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CHEMISTRY 20

LEARNING FACILITATOR'S MANUAL

MODULES 1-7

Distance Learning

Alberta EDUCATION

JUN 2 6 1994

Chemistry 20

LEARNING FACILITATOR'S MANUAL

Distance Learning

Alberta EDUCATION

Note

This Chemistry 20 Learning Facilitator's Manual contains answers to teacher-assessed assignments and the final test; therefore, it should be kept secure by the teacher. Students should not have access to these assignments or the final test until they are assigned in a supervised situation. The answers should be stored securely by the teacher at all times.

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This document is intended for	
Students	
Teachers (Chemistry 20)	✓
Administrators	
Parents	
General Public	
Other	

Chemistry 20
Learning Facilitator's Manual
Modules 1-7
Alberta Distance Learning Centre
ISBN No. 0-7741-0893-2

Cover photo: NASA

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Teachers

Register with the Alberta Distance Learning Centre

The Alberta Distance Learning Centre is dedicated to upgrading and continually improving your Learning Facilitator's Manual so that it accurately reflects any necessary revisions we have had to make in the student assignments or the sample final test. The types of revisions that will be made are those that make the course more accurate, current, or more effective.

The ADLC will send you the **latest enhancements or minor upgrades** for your Learning Facilitator's Manual if you return the following registration card to: Alberta Distance Learning Centre, Box 4000, Barrhead, Alberta, T0G 2P0, Attention: Instructional Design and Development.

ADLC Learning Facilitator's Manual
Registration Card

First Name _____ Surname _____

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School Address _____

City _____ Postal Code _____

Course Title _____ Approximate Date of Purchase _____

You can help ensure that distance learning courseware is of top quality by letting us know of areas that need to be adjusted. Call the Alberta Distance Learning Centre free of charge by using the RITE line and ask for the Editing Unit. Also, a Teacher Questionnaire has been included at the back of the Learning Facilitator's Manual. Please take a moment to fill this out.

We look forward to hearing from you!

Contents

Introduction 1

Overview of the Program of Studies 3

Overview of Chemistry 20 6

Structure of the Learning Package 7

Using This Learning Package in the Classroom 10

Evaluation 14

Introducing Students to the System 17

Module 1 19

Module 2 27

Module 3 35

Module 4 43

Module 5 52

Module 6 61

Module 7 69

Answer Key to the Final Test 77

Student's Copy of the Final Test

Teacher Questionnaire

Introduction

A survey of these course materials will confirm that this new learning package has been specially designed for many kinds of teachers working in a variety of situations.

Which Category Do You Fit?

- ❑ Small Schools Teacher
  - ❑ inexperienced
  - ❑ experienced, but in other subject areas
  - ❑ experienced in teaching Chemistry 20, but wanting to try a different approach
- ❑ Distance Learning Teacher
  - ❑ travelling to schools within the jurisdiction
  - ❑ using facsimile and teleconferences to teach students within the area
- ❑ Larger Schools Teacher
  - ❑ inexperienced
  - ❑ experienced in teaching Chemistry 20, but wanting to try a different approach

Because these materials have been created by experienced classroom teachers and distance learning specialists, they have many advantages for students and teachers regardless of their situations.

Advantages for Students

- incorporates a strong learner-centred philosophy
- promotes such qualities in the learner as autonomy, independence, and flexibility
- is developed through media which suit the needs and circumstances of the learner
- reflects the experiential background of Alberta students
- opens up opportunities by overcoming barriers that result from geographical location
- promotes individualized learning, allowing learners to work at their own pace

Advantages for Teachers

- allows teachers maximum teaching time and minimizes preparation time
- includes different routes through the materials to suit different learners
- incorporates a wide range of teaching strategies, in particular those using independent and individual learning
- delivers curriculum designed by education specialists that reflects the Alberta Education Program of Studies with an emphasis on Canadian content
- provides learning materials which are upwardly compatible with advanced educational technology

Does it sound like something you could use?

This Learning Facilitator's Manual begins with an overview of the current Alberta Education Program of Studies for Chemistry 20. This summary is included for inexperienced teachers or those teachers who have found themselves teaching Chemistry 20 when their training is in other subject areas. This brief summary is not meant to replace the Alberta Education Program of Studies, but rather to help teachers confirm the highlights of the program.

Other parts of this introduction have also been included to help teachers become familiar with this new learning package and determine how they might want to use it in their classroom.

Beyond the introduction the guide itself contains answers, models, explanations, and other tips generated by the teachers who authored this course.

The module booklets and LFMs are the products of experienced classroom teachers and distance learning specialists. It is the hope of these teachers that their experience can be shared with those who want to take advantage of it.

Overview of the Program of Studies

The Chemistry 20/30 program is one result of Alberta Education's Secondary Education Review of 1985. The policy set forward by this review established new requirements for high school graduation. High school students are now required to complete a minimum of two science courses (eight credits) to obtain a General High School Diploma and three science courses (fifteen credits) to obtain an Advanced High School Diploma. This increased demand for science credits has led to a restructuring of the science programs in Alberta.

The various course sequences in the senior high science program are illustrated in the *Senior High Science Teacher Resource Manual*, 1992, Curriculum Branch, Alberta Education.

Science, Technology, and Society

The 1985 policy statement, *Secondary Education in Alberta*, also directed the new high school science program to emphasize the application of basic scientific concepts and principles in the real world. The new high school science program has achieved this by emphasizing the interrelationship of science, technology, and society (STS). The STS approach is intended to provide students with a more balanced science education, one with an emphasis on science in the real world, rather than focussing on a body of knowledge isolated from its social context.

The teaching of science using the STS approach must centre on the development of scientifically literate and responsible citizens capable of using scientific knowledge wisely. The STS approach to science challenges students by developing scientific literacy through experimentation and investigation. This approach motivates students to learn more about science and to apply what they learn to other situations.

Technology is often the main point of contact individuals have with science. High school students are intrigued by the ever-developing gadgets and processes that characterize this age. There is therefore a tremendous opportunity, when dealing with the relationship between science and technology, to make the subject come alive. Science deals with gravity and friction, but technology gives civilization the wheel. While science asks *why*, technology asks *how*. Science is aimed at increasing human understanding and ability to explain nature. Technology is aimed at developing devices or processes that have practical purposes.

Science and technology affect every aspect of the daily life of Canadians. Both science and technology are involved in areas as diverse as communications, travel, agriculture, and waste management. But what is science and what is technology? Are they the same or are they different? How do science and technology affect society? How does society control science and technology? If students are to become enlightened, contributing citizens in a constantly changing society, they will need to know the answer to these questions.

Scientific literacy is an important goal of secondary school education, as it provides a means for asking and answering some very important questions.

A New Chemistry Curriculum

Within the new science program framework, all science courses have several aspects in common:

- There are a common rationale and philosophy, common goals, and general learner expectations.
- Students focus on learning the big interconnecting ideas and principles.
- There is an increased emphasis on developing methods of inquiry that characterize the study of science.
- The students gain an appreciation for the roles of science and technology in understanding nature and the environment, as well as the societal implications of science and technology.
- The context for learning is made relevant to the students by providing concrete experiences that students can relate to their world.
- The students are placed at the centre of their own learning which creates a more active learner with increased responsibilities.
- The inquiry process allows students to exercise their creativity and develop critical problem-solving skills through experimentation, problem-solving activities, and independent study.

The Chemistry 20/30 program emphasizes the key science themes: energy, matter, change, systems, diversity, and equilibrium. Chemistry 20 focuses on matter, systems, change, and diversity. Within these themes, students can develop an appreciation for chemistry's place in their world, as well as its connections to other science disciplines.

Science Skills Framework

Biology **Chemistry** **Physics** **Science**

The development of the new science programs has necessitated a review of assessment methods. Since the growth of science problem-solving skills in students is a priority of the science curricula, assessment methods must reflect this emphasis.

The document, *A Model for the Assessment and Evaluation of Scientific Problem-Solving Skills*, Draft, June 8, 1992, has direct implications for ADLC students and school students using distance learning materials. The following proposal attempts to incorporate the evaluation scheme into distance learning materials.

There are six categories in which the science skills of students will be assessed:

A. Initiating and Planning
B. Collecting and Recording
C. Organizing and Communicating
D. Analysing
E. Connecting, Synthesizing, and Integrating
F. Evaluating the Process or Outcome

Each category will be assessed according to a level scheme as discussed in the document. This scheme will need to be explained to students. Each course will have a standard explanation outlining the assessment model in Module 1.

Each course will have a science skills spreadsheet that allows students to record their progress in completing the science skills component of selected assignment questions throughout the course. The Chemistry 20 spreadsheet is in the appendix of Module 1. Science skills could be evaluated in the context of a lab investigation, a research project, a case study, or a group project. The framework for scientific problem-solving skills is explained in the Appendix of Module 1.

Each course will have to ensure that students have opportunities to be evaluated in each of the skills. In addition, students will need to be given formative practice at developing the skills throughout the activities and investigations. **Note:** The skill level indicated by the teacher to the student in the assignment questions is **NOT** reflected in the mark of the questions.

The evaluation of these skills will be ongoing throughout each science course. Students will be encouraged to do self-evaluation as well as a summative evaluation that focuses on growth and improvement.

Self-Evaluation

- When students do the activities in their module booklets, the science skills icon will reinforce which skills are being practiced. Students will be encouraged to reflect on their skill level.

- When students complete a question in the assignment that focuses on a science skill, they will be asked to evaluate the level of their response before it is submitted for grading. The teacher marking the assignment will then supply the student with his or her evaluation of the response along with a concise explanation if the level is different from what the student suggested.

- This area of self-evaluation will be explored further and enhanced for the 30-level courses.

- Self-evaluation concludes by students analysing their own progress as displayed on the spreadsheet. A mark will be given for this spreadsheet upon its completion. Each time their assignments are returned, the students are expected to transfer both the teacher level assessment and their own level assessment to the spreadsheet.

Summative Evaluation

- The level of a student's performance will be determined by the teacher throughout the course. As shown in Self-Evaluation, the level of performance for a particular science skill or set of skills will be assessed in the assignment questions that have been "flagged."

- The students will carefully track their progress throughout the course by recording their level and the teacher's level of assessment of achievement on their spreadsheet. The teacher will keep an on-going record of all teacher level assessment.

Overview of Chemistry 20

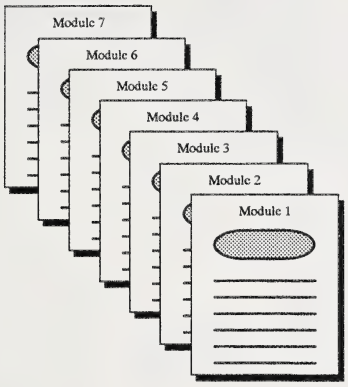
The ADLC Chemistry 20 course is made up of seven modules. Modules 1 and 2 deal with matter that forms solutions. Modules 3 and 4 deal with aspects of stoichiometry. Module 5 deals with chemical bonding. Modules 6 and 7 deal with organic chemistry.

The sequence of modules follows the Chemistry 20 program of studies as outlined by the Curriculum Branch, Department of Education. The following graphic illustrates the relationship between the program of studies and the Chemistry 20 program as produced by the Alberta Distance Learning Centre. The recommended percentage of available instructional time is also given for each module.

Chemistry 20 Program of Studies	ADLC Chemistry 20	
Unit 1 **Matter as Solutions, Acids, Bases, and Gases**	**Module 1** **Solutions**	14%
	Module 2 **Acids, Bases, and Gases**	16%
Unit 2 **Quantitative Relationships in Chemical Changes**	**Module 3** **Quantitative Relationships**	18%
	Module 4 **Quantitative Analysis**	12%
Unit 3 **Chemical Bonding in Matter**	**Module 5** **Chemical Bonding**	15%
Unit 4 **An Introduction to Organic Chemistry**	**Module 6** **Organic Compounds**	13%
	Module 7 **Organic Reactions**	12%

Structure of the Learning Package

Module Booklets



The print components involve many booklets called modules. These modules contain guided activities that instruct students in a relevant, realistic setting, as well as assignments that can be used for formative and summative assessments.

The modules have been specially designed to promote such qualities in the learner as autonomy, independence, and flexibility. Writers have incorporated such teaching strategies as working from the concrete to the abstract, linking the old to the new, getting students actively involved, and using advance, intermediate, and post organizers. Many other techniques enable learners to learn on their own for at least some of the time.

Contents
Overview Evaluation
Section 1 Activity 1 Activity 2 etc. Assignment
Section 2 Activity 1 Activity 2 etc. Assignment
Section 3 Activity 1 Activity 2 etc. Assignment
Section 4 Activity 1 Activity 2 etc. Assignment
Module Summary

The structure of the module booklets follows a systematic design. Each module begins with a detailed table of contents which shows the students all the main steps. It acts as an organizer for students. The overview introduces the module topic or theme. A graphic representation has been included to help visual learners and poor readers. The introduction also states the weightings of each assignment and provides instruction for setting up the response pages that are submitted to the teacher.

The body of the module is made up of two or more closely related sections. Each section contains student activities that develop skills and knowledge centred around a theme.

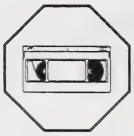
The activities may involve print, audio, video, computer, or laser videodisc formats. At times the student and the learning facilitator are allowed to choose the activity that best suits the student's needs and interests. Other activities such as the Extra Help and Enrichment are optional pathways. This flexibility caters to each student's personal situation.

The summary focuses on the skills and strategies that the student has learned.

The students should complete each section assignment after they have thoroughly reviewed the section. Some modules also have a final module assignment after the Module Summary.

Media

The package also includes references to media. Some types of media such as laser videodiscs are optional choices for students; however, there are activities that require students to view certain videos. These mandatory videos are listed on the following page. It is important that you acquire these videos as you are planning the course. In addition to the mandatory videos, optional videos have been mentioned at various points in the modules. A list of the optional videos is also included on the following page. More information about the videos can be found within the LFM.

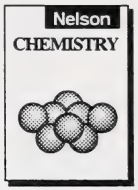


VIDEOCASSETTE

LASER VIDEODISC

Textbooks and Reference Books

The package requires students to use *Nelson Chemistry* as their textbook. Additional reference materials are indicated later in this manual.



Lab and Other Materials

The package includes references to lab materials. A list of necessary materials is included later in this manual.

Materials, Media, and Equipment

Mandatory Components

Equipment (Hardware)	Media	Materials

• VCR	• Mandatory Video List:
	(*Chemistry 20 Video 1*)
	– *PCBs in the Food Chain*
	– *World of Chemistry: Acids and Bases*
	– *The Mole Concept Series*
	  – Gas Volumes
	  – Combining Gas Volumes
	  – Avogadro's Hypothesis
	  – Relative Mass
	  – Relative Atomic Mass
	  – The Mole
	– *Choosing Science (Senior High School Science Series)*
		• LFM for Chemistry 20
		• one complete set of module booklets (7)
		• There is a final test.

Mandatory Components (ctnd.)

Equipment (Hardware)	Media	Materials
	• Mandatory Video List: (*Chemistry 20 Video 2*) – *Electron Arrangement and Bonding Series* – How Atoms Bond – Molecular Substances and Covalent Crystals – Metals and Ionic Bonds – *Organic Chemistry 2 Series* – ASA – Cosmetics – Soaps – *Organic Chemistry 1 Series* – Carbon the Compromiser – Polyethylene – Fixing Fuels – Harvest of Enzymes – *Planet Under Pressure Series* – Ozone	

Videocassettes or laser videodiscs used in the course may be available from the Learning Resources Distributing Centre or ACCESS Network. You may also wish to call your regional library service for more information.

Optional Components

Equipment (Hardware)	Media	Materials
• VCR • laser videodisc player	• laser videodiscs – *Chemistry at Work* – *The Chemistry Disc: Exothermic and Endothermic Reactions* – *Cosmic Chemistry* • Optional Video List: – *Hazardous Waste Management: Alberta's Success Story* – *The Chemistry of Solutions* – *Dynamic Equilibrium* – *Water, Water, Everywhere: Planet Under Pressure* – *What's on Tap?* – *Acid Rain: A North American Challenge* – *Chemical Equilibrium Series* – *Petroleum: River of Energy*	

Using This Learning Package in the Classroom

Conventional Classroom

Whether your classroom has desks in rows or tables in small groups, you may be most comfortable with a learning system that you can use with all your students in a paced style. In other words, you may want a package that will suit all of your students, so they can move through the materials as one group or several small groups. Because these materials contain different routes or pathways within each module, they can address various learning styles and preferences. The materials also include many choices within the activities to cater to different thinking levels and ability levels. Because of their versatility and flexibility, these materials can easily suit a conventional classroom.

Open-Learning Classroom

Open learning is the concept of opening up opportunities by overcoming barriers of time, pace, and place by giving the learners a package specially designed to enable them to learn on their own for at least some of the time.

Such a concept is not new. Many teachers can recite attempts to establish an individualized learning system as they recognized the importance of trying to personalize courseware to meet each individual student's needs. But these efforts often failed due to lack of time and lack of quality materials that conformed to Alberta specifications.

Due to advanced educational technology and improved Alberta-specific learning packages, a student-centred approach is now possible. Improved technology now allows us to provide support to learners individually, regardless of their pace or location. A teacher cannot be in twenty-eight places at one time offering guidance. However, media and a well-designed learning package can satisfy individual needs. Technology can also help provide an effective management system needed to track the students as they progress independently through the materials.

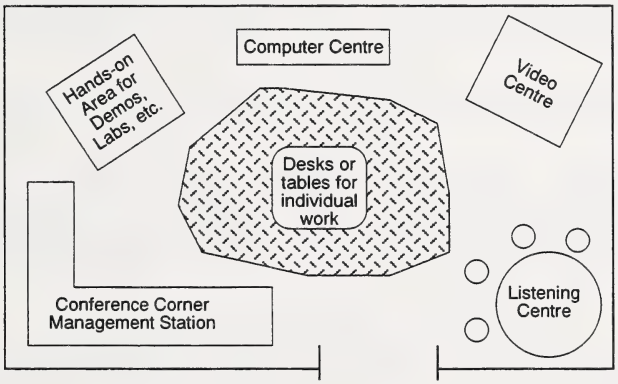
The key to a successful open-learning system depends on three vital elements: a learning package specially designed to enable students to learn effectively on their own for at least some of the time; various kinds of learner support; and a management system and style that ensures that the open-learning system runs smoothly.

The Key to a Successful Open-Learning System

Learning Package

The specially designed learning package needed for a successful open-learning system has been developed for you. The objectives teach current Alberta specifications using strategies designed for individualized instruction. As the learning facilitator, you need to be sure to have all the components in the learning package available to students as needed.

If adequate numbers of media are available to satisfy the demand, a centre can be established for specific media.



You may not have the luxury to have enough hardware to set up a permanent video or computer centre in your classroom. In that case, students should be encouraged to plan ahead. Perhaps every three to five days they should preview their materials and project when they would need a certain piece of media. This would allow you to group students, if necessary, or reserve media as required.

Support

Support is definitely a key element for successful learning, and when you're planning an individualized, non-paced program, you need to carefully plan when and how support will be given.

The materials contain a form of consistent support by providing immediate feedback for activities included in the module booklet. *High school students have solutions, models, explanations, and guides included in the appendix of every module booklet. These are included so students can receive immediate feedback to clarify and reinforce their basic understanding before they move on to higher levels of thinking.

As the learning facilitator, you may be needed to offer more personal guidance to those students having difficulty, or you may need to reinforce the need for students to do these activities carefully before attempting the section assignments.

The activities include choices and pathways. If a student is having difficulty, you may need to encourage that student to work on all the choices rather than one. This would provide additional instruction and practice in a variety of ways.

Another form of support is routine contact with each individual. This might be achieved with a biweekly conference scheduled by you, or as students reach a certain point (e.g., after each section is completed), they may be directed to come to the conference area.

Special counselling may be needed to help students through difficult stages. Praise and encouragement are important motivators, particularly for those students who are not used to working independently.

Direct teaching may be needed and scheduled at certain points in the program. This might involve small groups or a large group. It might be used to take advantage of something timely (e.g., election, eclipse, etc.), something prescheduled like the demonstration of a process, or something involving students in a hands-on, practical experience.

Support at a distance might include tutoring by phone, teleconferencing, faxing, or planned visits. These contacts are the lifeline between learners and distance education teachers, so a warm dialogue is essential.

Management

Good management of an open-learning system is essential to the success of the program. The following areas need action to ensure that the system runs smoothly:

- Scheduling, Distributing, and Managing Resources – As discussed earlier, this may require a need for centres or a system for students to project and reserve the necessary resources.

- Scheduling Students – Students and teachers should work together to establish goals, course completion timelines, and daily timelines. Although students may push to continue for long periods of time (e.g., all morning), teachers should discourage this. Concentration, retention, and motivation are improved by taking scheduled breaks.

- Monitoring Student Progress – You will need to record when modules are completed by each student. Your data might also include the projected date of completion if you are using a student contract approach.

Sample of a Student Progress Chart

Chemistry 20		Module 1	Module 2	Module 3	Module 4	Module 5	Module 6	Module 7	Final Test
Billy Adams	P								
	A								
Louise Despins	P								
	A								
Violet Klaissian	P								
	A								
P = Projected Completion Date A = Actual Completion Date									

The student could keep a personal log as well. Such tracking of data could be stored easily on a computer.

- Recording Student Assessments – You will need to record the marks awarded to each student for work completed in each section assignment. The marks from these assignments will contribute to a portion of the student's final mark. Other criteria may also be added (a special project, effort, attitude, etc.). Whatever the criteria, they should be made clear to all students at the beginning.

Sample of a Student Assessment Chart

Course Name	Module 1	Module 2	Module 3	Module 4	Module 5	Module 6	Module 7	Year's Average	Final Test	Final Mark
Billy Adams	**67**	**65**	**54**	**47**	**78**	**67**	**63**	**63**		
Louise Despins	**43**	**50**	**54**	**55**	**48**	**42**	**49**	**49**		
Violet Klaissian	**65**	**65**	**66**	**68**	**67**	**70**	**67**	**67**		

Letter grading could easily be substituted.

- Recording Effectiveness of System – Keep ongoing records of how the system is working. This will help you in future planning.

Sample of a System Assessment Chart

Module 1			
Date	Activities	Assignments	Resources/Media

The Role of the Teacher in an Open-Learning Classroom

The teachers in a conventional classroom spend a lot of time talking to large groups of learners. The situation in open learning requires a different emphasis. Teachers will probably meet learners individually or in very small groups.

With this approach it is necessary to move beyond the idea of a passive learner depending largely on a continually supportive teacher. The teacher must aim to build the student's confidence, to stimulate the learner into self-reliance, and to guide the learner to take advantage of routes that are most meaningful and applicable to the learner.

These materials are student-centred, not teacher-centred. The teacher needs to facilitate learning by providing general support to the learner.

Evaluation

Evaluation is important to the development of every learner. Data gathering and processing, and decision making, at the student and teacher level, serve as means of identifying strengths and weaknesses.

These specially designed learning packages contain many kinds of informal and formal evaluation.

Observation

In the classroom the teacher has the opportunity to see each student perform every day and to become aware of the level and nature of each student's performance.

Observations are more useful if they are recorded in an organized system. The following list of questions is a sample of types of observations and how they can be collected.

Observation Checklist

	B. Adams	L. Despins	V. Klaissian	H. Smith	K. Dalley
1. Does the student approach the work in a positive manner?					
2. Is the student struggling with the reading level?					
3. Does the student make good use of time?					
4. Does the student apply an appropriate study method?					
5. Can the student use references effectively, etc.?					

Observation may suggest a need for an individual interview with a student.

Individual Conferences

Individual conferences may be paced (scheduled) by the calendar, at certain points in the module, or they may be set up only as needed or requested.

During these conferences teachers can determine the student's progress and can assess the student's attitudes toward the subject, the program, school, and self, as well as the student's relationship with other students. With guided questions the teacher can encourage oral self-assessment; the student can discuss personal strengths or weaknesses in regard to the particular section, module, or subject area.

Self-Appraisal

Self-appraisal helps students recognize their own strengths and weaknesses. Through activities that require self-assessment, students also gain immediate feedback and clarification at early stages in the learning process. Teachers need to promote a responsible attitude toward these self-assessment activities. Becoming effective self-assessors is a crucial part of becoming autonomous learners. By instructing, motivating, providing positive reinforcement, and systematically supervising, the learning facilitator will help students develop a positive attitude toward their own progress.

For variation, students may be paired and peer-assessing may become part of the system. The teacher may decide to have the student self-assess some of the activities, have a peer assess other activities, and become directly involved in assessing the remainder of the activities.

When the activities have been assessed, the student should be directed to make corrections. This should be made clear to students right from the start. It is important to note the correct association between the question and the response to clarify understanding, aid retention, and be of use for study purposes.

Many of the activities include choices for the student. If the student is having difficulty, more practice may be warranted, and the student may need to be encouraged to do more of the choices.

Each section within a module includes additional types of activities called Extra Help and Enrichment. Students are expected to be involved in the decision as to which pathway best suits their needs. They may decide to do both.

Self-appraisal techniques can also be introduced at the individual conferences. Such questions as the following might be included:

- What steps are you taking to improve your understanding of this topic?
- What method of study do you use most?
- How do you organize your material to remember it?
- What steps do you follow when doing an assignment?
- What could you do to become an even better reader?
- Do you have trouble following directions?
- Did you enjoy this module?

A chart or checklist could be used for recording responses.

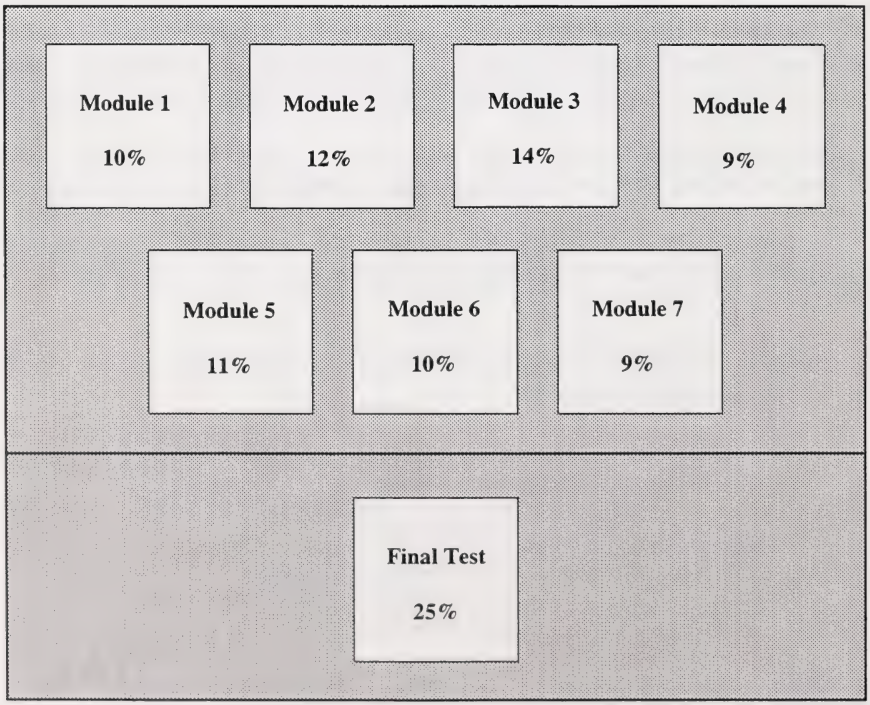
Informal Evaluation: Assignments

Informal evaluation, such as the assignments included in each module, are an invaluable aid to the teacher. They offer ongoing assessment information about the student's achievement and the behaviour and attitudes that affect that achievement.

Each module contains a number of assignments. These assignments assess the knowledge or skills that the student has gained from the module. **The student's mark for the module may be based solely on the outcome of learning evident in the assignments; however, you may decide to establish a value for other variables such as attitude or effort.** It is important that you establish at the beginning which outcomes will be evaluated, and that all students clearly understand what is expected.

Final Test

All LFMs include a formal final test which can be photocopied for each member of the class. The test, closely linked to the learning outcomes stated in the module booklets, gives the teacher precise information concerning what each student can or cannot do. Answers, explanations, and marking guides are also included. The value of the final test and each module is the decision of the classroom teacher. Following is a suggestion only.



Introducing Students to the System

Your initiation to these learning materials began with a basic survey of what was included and how the components varied. This same process should be used with the class. After the materials have been explored, a discussion might include the advantages and the disadvantages of learning independently or in small groups. The roles of the students and teacher should be analysed. The necessary progress checks and rules need to be addressed. Your introduction should motivate students and build a responsible attitude toward learning autonomously.

Skill Level

It is important for students to understand that there are certain skills that they will need in order to deal successfully with the course materials. They are listed below:

- understanding and using instructional materials (table of contents, index, list of illustrations, WHMIS labels associated with lab materials, appendices, bibliography, and glossary)
- interpreting lab data, graphs, and charts
- using reference materials
- utilizing science skills
- using a scientific calculator

Other general skills are using reliable study methods, outlining, and learning to read at a flexible rate.

To decide the level and amount of instruction needed to accommodate the varied levels among students, you may wish to prepare and administer skill inventories or pretests. If most students need help with a particular skill, you may want to plan a total class instructional session. If only certain students lack a skill, you may want to set up a temporary skill group to help students who need it, or you may want to develop a skills file for this purpose.

Reading Level

These course materials are largely print based, but poorer readers need not be discouraged. It is important that you assure the students that these materials have been designed for easy reading. The authors have employed special strategies that lower and control the reading level. Some of them are

- the conscious selection of vocabulary and careful structuring of sentences to keep the materials at an independent reading level
- the integration of activities, examples, and illustrations to break text into appropriate-sized chunks
- the inclusion of many kinds of organizers (advance, graphic, intermediate, concept mapping, post organizers) to help give students a structure for incorporating new concepts

- the recognition that vocabulary and concepts are basic to understanding content materials and, thus, must be handled systematically (defined in context, marginal notes, footnotes, and often in a specialized glossary)

- the acknowledgement that background knowledge and experience play a vital role in comprehension

- the systematic inclusion of illustrations and videos to help poorer readers and visual learners, and audiocassettes and software as an alternative to print-based learning

- a variety of formats (paragraphs, lists, charts, etc.) to help poorer readers who do not absorb or retain main ideas easily in paragraph format

- the inclusion of media and activity choices to encourage an active rather than passive approach

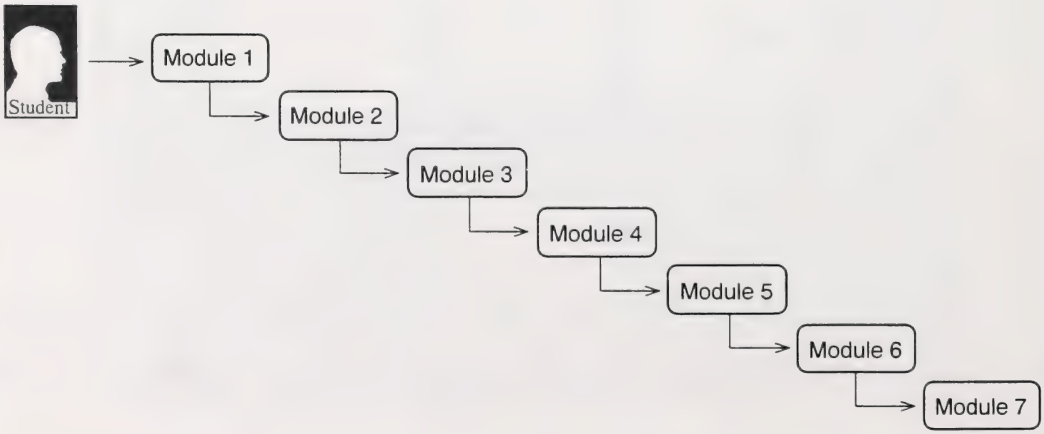
- instruction in a meaningful setting rather than in a contrived, workbook style

- using purposeful reading, viewing, and doing to produce better interpretation of the course materials

- the recognition that students need structured experiences when reading, viewing, or listening to instructional materials: developing pupil readiness, determining the purpose, providing guided instruction and feedback, rereading if necessary, and extending (This structure closely resembles the reading process.)

To help make the learning package more readable, you can begin your module preparation by reading (viewing, listening to) all the related materials that are going to be used. You need a solid background in order to assess and develop a background knowledge for students. The students' experiential bases may be assessed through brainstorming sessions concerning the topic, or by using visuals and guided questions to predict what the topic might be about.

It is recommended that you start with Module 1 because this module includes basic introductory information, and it is also recommended that you end with Module 7 because this module acts as a summary or culmination.



Module 1: Solutions

Overview

One major emphasis of this module is the qualitative analysis of aqueous solutions. Many scientific, technological, and societal applications are brought in as a context for learning. Section 1 deals with the applications of solutions and explains how different solutes are dissolved, as well as providing the framework for science skills assessment.

Section 2 explains how solutions are described by chemists and industry. It shows how a solution can be made to a precise measurement and how concentration is described quantitatively.

Section 3 deals with identifying solutions in terms of solubility properties and concentrations of ions. It relates to Section 1 since solubility of reaction products can be used to identify ions in solution. It also relates to Section 2 since the concentration of ions is another method of describing a solute.

The Appendix contains charts outlining the expectations at various levels in science skills assessment. The spreadsheet for recording results follows these charts. The chart may be photocopied or reproduced as required. It is to be handed in with the final assignment in Module 7.

MODULE 1: SOLUTIONS

Section 1: Identity and Applications

- Describe science skills.
- Identify solutions.
- Explain solution process.
- Classify solutes as electrolyte or non-electrolyte.
- Identify ions based on colour and flame tests.
- Give reasons for using solutions.

Section 2: The Importance of Concentration

- Do concentration and dilution calculations.
- Make solutions.
- List ways of describing concentration.
- Use concentration values to make decisions.

Section 3: Dissociation and Equilibrium

- Identify ions based on solubility.
- Explain equilibrium.
- Write dissociation equations.
- Calculate concentration of ions.

Evaluation

The evaluation of this module will be based on three assignments:

Section 1 Assignment	**35 marks**
Section 2 Assignment	**25 marks**
Section 3 Assignment	**40 marks**
TOTAL	**100 marks**

Materials and Equipment

The following is a list of materials necessary for completing the investigations and activities in Module 1. Amounts stated represent requirements per student.

Section 1: Activity 1

Investigation 1.1: Stain Removal

See page 19 of *Nelson Chemistry* for a list of materials.

Investigation: Aluminum in Copper(II) Chloride

- 10 cm × 10 cm piece of aluminum foil
- 250 mL beaker
- 5 g copper(II) chloride
- stirring rod
- 75 mL distilled water
- thermometer

Section 1: Activity 2

Investigation: The Conductivity of Solutions

- conductivity apparatus – This can be an ammeter, a multi-tester, or a device made using the directions in Addison Wesley's *Small-Scale Chemistry Laboratory Manual.*
- 0.10 g (1 mL or 1/4 tsp.) table salt
- 15.0 mL of 0.10 mol/L hydrochloric acid
- stirring rods
- (4) 50 mL beakers
- 60 mL distilled water
- 0.10 g (1 mL or 1/4 tsp.) white table sugar
- test tubes
- scoopula

Section 1: Activity 3

Investigation 5.2: The Iodine Clock Reaction

- 100 mL Solution A: Dissolve 4.28 g potassium iodate, KIO_3, in enough water to make 1.00 L of solution.
- 100 mL Solution B: Make a paste of 4.00 g of soluble starch and add it to 800 mL boiling water. Cool the mixture; then add 0.200 g of sodium disulphite, $Na_2S_2O_5$. Transfer the mixture to a 1.00 L flask. Add 5.0 mol/L sulphuric acid solution (approximately 5.0 mL) and test the mixture for time to react. Add the $H_2SO_{4(aq)}$ solution until the reaction time is adjusted to 10 s. **Note:** This solution must be acidified just prior to the lab.

- 10 mL graduated cylinder
- (4) test tubes
- thermometer
- 10.0 mL graduated pipet
- test tube rack
- stopwatch
- water bath (hot water and ice water)

Section 2: Activity 2

Investigation 7.5: Preparation of a Standard Solution from a Solid

See page 186 in *Nelson Chemistry* for a list of materials. Additional items are listed here.

- 5 g copper(II) sulphate pentahydrate
- 200 mL distilled water
- delivery pipet (10 mL) or graduated pipet

Investigation 7.6: Preparing a Standard Solution by Dilution

See page 188 in *Nelson Chemistry* for a list of materials.

Section 3: Activity 1

Investigation: Precipitation Reactions

For this activity, dropper bottles and spot plates or acetate sheets are a good way to do this lab. Solutions of 0.100 mol/L are absolutely necessary if you are going to see the precipitates formed. You could use micropipets and microplates. This would be very economical and would prevent waste.

- 1 mL sodium sulphate solution
- 1 mL sodium chloride solution
- 1 mL sodium nitrate solution
- distilled water
- 1 mL sodium sulphide solution
- 1 mL barium nitrate solution
- 1 mL copper(II) nitrate solution
- acetate sheet or spot plate
- 1 mL sodium phosphate solution
- 1 mL calcium nitrate solution
- 12 toothpicks
- 2 eye droppers

Section 3: Activity 2

Investigation 5.3: Sequential Qualitative Analysis

See page 122 in *Nelson Chemistry* for necessary materials.

Investigation: Comparing the Degrees of Conductivity of Two Solutions

- conductivity tester
- 0.100 mol/L barium hydroxide solution
- 0.100 mol/L sodium hydroxide solution
- (2) 50.0 mL beakers

Additional Resources

_____. 1993. *Small-Scale Chemistry Laboratory Manual, Teacher's Edition.* California: Addison-Wesley Publishing Company, Inc.

Summerlin and Ealy. 1988. *Chemical Demonstrations: A Source Book For Teachers.* Vol. 1, 2d ed. Washington, D.C.: American Chemical Society.

Possible Media

Videos

The Chemistry of Solutions. (1992) (ACCESS Network)

Dynamic Equilibrium. (1984) (ACCESS Network – VC324702)

Hazardous Waste Management: Alberta's Success Story. (1991) Vicom, Edmonton.

PCBs in the Food Chain. (1990) Films for the Humanities and Science, Inc., New Jersey.

Water, Water, Everywhere: Planet Under Pressure. (1991) TV Ontario.

What's on Tap? (1991) Coronet Film and Video.

Laser Videodiscs

Chemistry at Work. (1991) Videodiscovery.

The Chemistry Disc: Exothermic and Endothermic Reactions. (1992) B.C.I.T./Matrix Interactive Video Systems Corporation.

Cosmic Chemistry. (1992) Optical Data Corporation, New Jersey.

Note: Some of the suggested media may not be authorized by Alberta Education. Teachers should use their own discretion regarding the use of these resources in their classroom.

Section 1: Identity and Applications

Key Concepts

This section defines solutions and shows how to identify a solution as an electrolyte or non-electrolyte. It explains why solutions are easy to use and uses Arrhenius' theory to explain the solution process. Qualitative tests such as the flame test and solution colour are done to identify solutes dissolved in solutions.

Teaching Suggestions

This section focuses on how solutes can be identified as acids, molecules, or ions. In an STS context you could begin by showing a video on acid rain or toxic waste. You could also begin by investigating the water sources used by the individuals in the class. The students could debate whether or not cities and towns should fluoridate the water.

The investigation in Activity 1 is a simple one if you have a conductivity tester that shows conductivity in various degrees. Make sure that the water used is distilled and that the conductivity tester does not register any conductivity for the control. You might introduce the investigation by testing drinking water first and comparing it to the distilled water.

The investigation in Activity 3 is a difficult one to set up but students find it interesting and fun to do. This investigation is set up so that the students will attempt to solve the problem scientifically. This is somewhat dishonest because they soon realize that it is easier to do by hit-and-miss testing. The lesson of this investigation is that in a technological application, the goal is more important than the method. To increase the possibility that the students might stray from their original procedures, you could make the investigation a contest. You might also just let them try the investigation as a fun activity with no introduction, then do a lesson afterwards on the difference between scientific problem solving and everyday problem solving.

Section 1: Assignment Answer Key (35 marks)

1. Initiating and planning would include purpose, problem, prediction, experimental design, materials, and procedure. **(2 marks)**

2. a. Observations are raw data or empirical data collected – measurements, qualitative properties.

   Inferences are conclusions based on one or more observations. **(1 mark)**

   b. Many answers are possible. The answer must correctly reflect an observation and an inference related to each other.

   Example observation – A red-orange solid formed on the surface of the metal.

   Example inference – The red-orange solid was rust. **(1 mark)**

3. a. molecular compounds
   b. ions
   c. dissolving
   d. dilute solutions
   e. homogeneous **(5 marks)**

4. a. Materials should include the following:

   - solutions A, B, C
   - conductivity tester
   - 50 mL beakers **(1 mark)**

   b. Procedure steps could include the following:

   - Prepare an evidence table for recording results.
   - Test each solution with a conductivity apparatus.
   - Record results in the evidence table. **(2 marks)**

c. An evidence table similar to the following may be shown.

The Conductivity of Three Solutions

Solution	Degree of Conductivity
1	
2	
3	

(1 mark)

d. **Explanation**

One of the solutions would be expected to show no light when tested with the conductivity apparatus. The other two solutions should light up the apparatus. **(2 marks)**

5. When calcium nitrate and ethanol dissolve in water, the calcium nitrate forms a conducting solution and the ethanol forms a non-conducting solution. The calcium nitrate dissociates into calcium ions and nitrate ions which are then surrounded by the water molecules. The ethanol separates into its individual molecules and then water molecules surround each one. **(4 marks)**

6. **Analysis**

Solution 1 is an ionic compound because it conducts and contains K^+ ions according to the flame test. It is KCl.

Solution 2 is an ionic compound that contains Cu ions because it conducts and has a green colour during the flame test. It is Cu_2SO_4.

Solution 3 is a molecular compound because it does not conduct. It is methanol.

Solution 4 is an ionic compound because it conducts. It contains permanganate because the solution colour is purple, and K^+ since the flame test colour is violet. It is $KMnO_4$. **(8 marks)**

7. Blood plasma is an aqueous solution that is part of a living system. The major solutes are ions, proteins, oxygen, and fatty acid. Water is the solvent. The presence of ions in the plasma can be identified by a conductivity test. The presence of specific ions can be confirmed by a flame test.

Any other solution may be named. The major solutes and the solvent should be named. A correct conductivity or flame test for identifying ions should also be given. **(8 marks)**

Section 2: The Importance of Concentration

Key Concepts

Section 2 involves the student in the preparation of solutions by doing calculations. The student will calculate concentration and the mass of the solute required to prepare the solution. Techniques for preparing solutions from solid reagents and from concentration are also learned. The importance of lab safety when using solutions is studied. Toxic chemicals such as mercury and DDT in the environment are also studied.

Teaching Suggestions

This section involves concentration and how you can use it to monitor the environment. There is also an activity on lab safety.

This section could be introduced with a video on pollution and its effects on a food chain. You may also wish to introduce this unit with a research project on bioaccumulation. Other video topics may involve mercury.

Section 2: Assignment Answer Key (25 marks)

1. $n = ?$
$C = 0.325$ mol/L
$v = 2.00$ L

$n = Cv$
$= 0.325 \text{ mol/L} \times 2.00 \text{ L}$
$= 0.650 \text{ mol}$

$m = ?$
$n = 0.650$ mol
$M = 180.18$ g/mol $C_6H_{12}O_6$

$m = nM$
$= 0.650 \text{ mol} \times 180.18 \text{ g/mol}$
$= 117 \text{ g}$

The mass of glucose required is **117 g**. **(4 marks)**

2. The steps that are followed in preparing the solution are as follows:

- Measure 1.11 g of solid calcium chloride.
- Dissolve the calcium chloride in 50 mL of water in a beaker.
- Pour the solution into a 100 mL volumetric flask.
- Add water until the level reaches the calibration mark.
- Stopper the flask and invert it several times. **(3 marks)**

3. $n = ?$
$m = 4.05$ g
$M = 161.98$ g/mol Na_2CrO_4

$$n = \frac{m}{M} = \frac{4.05 \text{ g}}{161.98 \text{ g/mol}} = 0.0250 \text{ mol}$$

$v = ?$
$n = 0.0250$ mol
$C = 0.100$ g/mol

$$v = \frac{n}{C} = \frac{0.0250 \text{ mol}}{0.100 \text{ mol/L}} = 0.250 \text{ L}$$

The volume of solution that can be prepared is **0.250 L**. **(4 marks)**

4. a. $v_i = ?$
$C_i = 0.50$ mol/L
$v_f = 0.200$ L
$C_f = 0.200$ mol/L

$$v_i = \frac{C_f v_f}{C_i} = \frac{0.200 \text{ mol/L} \times 0.200 \text{ L}}{0.50 \text{ mol/L}} = 0.080 \text{ L or } 80 \text{ mL}$$

The volume you need to dilute is **0.0800 L** or **80 mL**. **(2 marks)**

b. $v_f - v_i = ?$
$= 200 \text{ mL} - 80 \text{ mL}$
$= 120 \text{ mL}$

The volume of distilled water required is **120 mL**. **(2 marks)**

5. As the toxins pass through each level of the food chain, they are stored and magnified. Therefore, when mammals are exposed to the toxins, the toxins may have concentrated through two or three levels. This makes the toxin level quite high and dangerous. **(2 marks)**

6. Some risks and benefits may be as follows:

Risks	Benefits
• The mercury may be impossible to remove from the sulphur. • Mercury is a toxic substance. • Mercury can undergo biomagnification. • Disposal of mercury is difficult.	• The plant is a part of the economy of Danby. • The concentrations are low (ppb). • The gas field is a useful resource.

Answers to the question posed may vary according to what risks or benefits the student judges to have greater importance. The student may conclude that since there are more risks than benefits, the gas stream should not be used.

The student may conclude that if the company cannot safely contain the mercury, they would not use the gas stream. If the student logically justifies his or her answer after listing all risks and benefits, then he or she should receive full marks. **(8 marks)**

Section 3: Dissociation and Equilibrium

Key Concepts

Section 3 shows how a solubility chart can be developed from a series of double replacement reactions. The section applies the use of the solubility chart to the solubility of compounds and to selective precipitation of ions for qualitative identification. Dissociation of ions and calculations involving concentration of ions are performed in this section. This leads to the concept of dynamic equilibrium. This section deals solely with dynamic equilibrium in saturated solutions.

Teaching Suggestions

A review of writing chemical reactions is useful. Also a review of reaction evidence would help students. The unit on equilibrium needs more visual cues for the student. A video or demonstration is the best way of introducing equilibrium.

Section 3: Assignment Answer Key (40 marks)

1.

	$Na_2SO_{4(aq)}$	$K_2SO_{4(aq)}$	$Hg_2SO_{4(aq)}$
$BaCl_{2(aq)}$	✔	✔	✔
$SrCl_{2(aq)}$	✔	✔	✔
$MgCl_{2(aq)}$			✔

(7 marks)

2. The student could use conductivity of solution. The aluminum nitrate should be more conductive because it is a strong electrolyte. When it dissociates, it separates into more ions than cadmium nitrate. **(3 marks)**

3. a. Sodium hydroxide is soluble. **(1 mark)**

   b. Lead(II) chloride is insoluble. **(1 mark)**

   c. Copper(II) carbonate is insoluble. **(1 mark)**

   d. Ammonium phosphate is soluble. **(1 mark)**

   e. Barium chloride is soluble. **(1 mark)**

4. a. $CaCl_{2(s)} \rightarrow Ca^{2+}{}_{(aq)} + 2\ Cl^{-}{}_{(aq)}$

$(NH_4)_2SO_{4(s)} \rightarrow 2\ NH_4^{+}{}_{(aq)} + SO_4^{2-}{}_{(aq)}$

$Al(NO_3)_{3(s)} \rightarrow Al^{3+}{}_{(aq)} + 3\ NO_3^{-}{}_{(aq)}$ **(3 marks)**

b.

Solute	Molar Concentration (mol/L)	[cations] (mol/L)	[anions] (mol/L)
$CaCl_2$	0.100	**0.100**	**0.200**
$(NH_4)_2SO_4$	**0.250**	0.500	**0.250**
$Al(NO_3)_3$	**0.300**	0.300	**0.900**

(6 marks)

5. a. The equation for the equilibrium is as follows:

$PbCl_{2(aq)} \leftrightarrows Pb^{2+}{}_{(aq)} + 2\ Cl^{-}{}_{(aq)}$ **(1 mark)**

b. The rate of dissolving and the rate of crystallizing are equal in the dynamic equilibrium. **(2 marks)**

c. There are two possible answers; either must be justified.

- Yes, the lead(II) chloride would eventually dissolve since the system is constantly undergoing a change but there would always be 1.5 g of solid on the bottom of the container. It is like the radioactive iodine dispersing through a saturated solution.
- No, the 1.5 g of solid lead(II) chloride would not dissolve because the solution at equilibrium is a saturated solution. It is at its maximum concentration. **(2 marks)**

6. a. Any soluble substance that contains Sr^{2+}, Ba^{2+} or Tl^{+} would actively precipitate SO_3^{2-}. **(1 mark)**

b. A sample balanced equation is as follows:

$Sr(NO_3)_{2(aq)} + Na_2SO_{3(aq)} \rightarrow SrSO_{3(s)} + 2\ NaNO_{3(aq)}$ **(2 marks)**

7. The analysis could be stated in a chart as follows:

Solution Number	Identity	Reason
1	strontium chloride	It is the only compound that will precipitate with sulphate and with silver. The strontium ions are insoluble with sulphate ions and the silver ions precipitate the chloride ions.
2	barium hydroxide	Barium is the only ion that is yellowish green during the flame test. The sulphate ions precipitate the barium ions and the silver ions precipitate the hydroxide ions.
3	ethanol	It is the only molecular compound. It does not conduct electricity.
4	lithium carbonate	It is the only ionic compound that does not precipitate with the sulphate ions. This distinguishes it from the strontium chloride solution. The silver ions precipitate the carbonate ions.

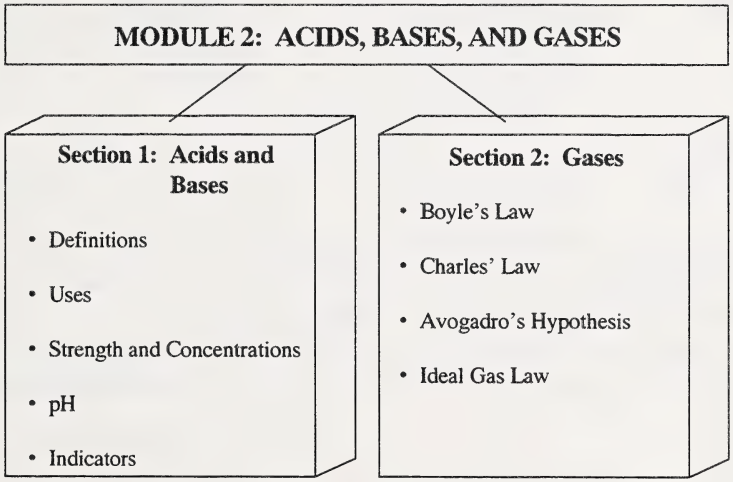
(8 marks)

Module 2: Acids, Bases, and Gases

Overview

The first section of this module emphasizes that students know how acids and bases affect a system, that they realize that contact with acids and bases is a common phenomena, and that acids and bases can be interacted with safely, even when strong and concentrated.

The second section emphasizes that although the gas laws allow several predictions as to how a system will be affected by changes in pressure, temperature, and number of moles, it was through the scientific process that the laws which govern the behaviour of the gases were developed.



Evaluation

The evaluation of this module will be based on two assignments:

Section 1 Assignment	**40 marks**
Section 2 Assignment	**60 marks**
TOTAL	**100 marks**

Materials and Equipment

The following is a list of materials necessary for completing the investigations and activities in Module 2. Amounts stated represent requirements per student.

Section 1: Activity 1

Investigation 5.1: Chemical Analysis

- conductivity apparatus
- 4 pieces of red litmus paper
- 4 pieces of blue litmus paper
- 1 g masses of each of calcium chloride, citric acid, glucose, and calcium hydroxide in separate vials labelled as unknowns A, B, C, D.
- 4 test tubes
- 40 mL distilled water

Section 1: Activity 2

Investigation: Common Household Acids and Bases

- water
- litmus paper

- A selection of common household items such as the following may be selected:

  - vinegar
  - antacid tablets
  - window cleaner
  - milk
  - coffee
  - tap water
  - lemon juice
  - pickles
  - trisodium phosphate
  - ASA tablets
  - oven cleaner
  - bleach
  - garden lime
  - baking powder
  - soft drinks
  - shampoo
  - drain cleaner
  - ketchup
  - boric acid (borax)
  - dish detergent
  - vitamin C
  - cream of tartar

Section 1: Activity 3

Investigation: Qualitative Analysis of Unknown Solutions

- 10 mL each of the following 0.10 mol/L solutions (in vials marked as unknowns 1-4):
  - hydrochloric acid, $HCl_{(aq)}$
  - acetic acid (vinegar), $CH_3COOH_{(aq)}$
  - potassium hydroxide, $KOH_{(aq)}$
  - potassium bromide, $KBr_{(aq)}$
- 1 mL (1/4 tsp.) sucrose or sugar, $C_{12}H_{22}O_{11(s)}$
- universal pH paper (hydrion paper) and standard colour chart
- distilled water
- conductivity apparatus
- test tubes (or suitable containers)

Section 2: Activity 1

Investigation: The Compressibility of Gases

- eye dropper
- water
- 100 mL graduated cylinder or narrow-necked glass

Investigation: Diffusion

Part A and Part B

- a few drops of concentrated $NH_{3(aq)}$ $\left(NH_4OH_{(aq)}\right)$
- long diffusion tube (glass tubing) about 1 m in length and 0.5 cm-2.0 cm in diameter
- metre stick
- a few drops of concentrated $HCl_{(aq)}$
- cotton batting
- eye dropper

Section 2: Activity 2

Investigation: The Effect of Pressure on the Volume of a Gas (Boyle's Law)

Part A

- 60 mL syringe (35 mL syringe or larger will do)
- retort stand
- five identical books
- utility clamps
- rubber stopper (No. 5 or larger)

Part B

- bathroom or household scale
- rubber stopper (No. 5 or larger)
- 60 mL syringe (35 mL syringe or larger will do)

Note: The preceding investigation can also be performed by substituting a milk carton and water for the books used in Part A. You would therefore need the following items:

- 2 L milk carton
- 100 mL graduated cylinder or measuring cup
- rubber stopper (No. 5 or larger)
- 2 L water
- 60 mL syringe (35 mL syringe or larger will do)

Section 2: Activity 3

Investigation: The Effect of Temperature on the Volume of a Gas (Charles' Law)

- 60 mL syringe (35 mL syringe or larger will do)
- 600 mL beaker or equivalent
- hot plate (or equivalent)
- ice
- thermometer (0°C-100°C)
- rubber stopper
- retort stand and clamps
- water

Section 2: Activity 5

Investigation: Verifying Charles' Law

- pail
- balloon
- alcohol thermometer
- hot and cold water
- plate
- measuring cup or graduated cylinder

Section 2: Activity 6

Investigation 6.1: Determining the Molar Mass of a Gas

See page 160 in *Nelson Chemistry* for a list of materials.

Additional Resources

Jenkins, F., et al. 1981. *Alchem*. Edmonton: J.M. LeBel Enterprises Ltd.

Wilbraham A.C., D.D. Staley, et al. 1993. *Addison-Wesley Chemistry*. 3d ed. Don Mills, Ontario: Addison-Wesley Publishing Company, Inc.

Possible Media

Video

Acid Rain: A North American Challenge. (1988) Minister of Supply and Services.

The Mole Concept Series. (1983) TV Ontario. (ACCESS Network)
Includes segments Avogadro's Hypothesis, Combining Gas Volumes, and Gas Volumes.

World of Chemistry Series. (1988) Annenberg/CPB Project with Raold Hoffmann, Magic Lantern Communications.
Includes a segment Acids and Bases.

Laser Videodisc

Cosmic Chemistry. (1992) Optical Data Corporation, New Jersey.

Section 1: Acids and Bases

Key Concepts

The emphasis in this section is the large role played by acids and bases in students' lives, both directly (domestic use) and indirectly (industrial use). Students should know what acids and bases are (definition) and how to recognize them by formula. The acidity or basicity of a solution should be expressed by students in terms of $[H^+]$ or pH.

Teaching Suggestions

- Activity 1
  - The ionization of an acid can be shown in this demonstration: Take a pure acid like glacial acetic acid and test conductivity; slowly add water and note the increase of conductivity.
  - A pH meter can be used to demonstrate the neutralization of an acid and a base.
- Activity 2
  - Field trips to H_2SO_4 - and NaOH-producing plants near Fort Saskatchewan would be very beneficial.
  - There are many safety films available covering the safe handling and treatment of acids and bases.

Section 1: Assignment Answer Key (40 marks)

1. a. In an acidic solution, $[H^+{}_{(aq)}]$ is greater than $[OH^-{}_{(aq)}]$. **(1 mark)**

   b. In a neutral solution, $[H^+{}_{(aq)}]$ equals $[OH^-{}_{(aq)}]$. **(1 mark)**

2. a. neutral substance **(1 mark)**

   b. Arrhenius acid **(1 mark)**

   c. Arrhenius acid **(1 mark)**

3. a. $C_2H_5OH_{(aq)}$, $H_2O_{(l)}$ **(1 mark)**

   b. $BaSO_{4(s)}$, $H_2O_{(l)}$ **(1 mark)**

   c. $HClO_{3(aq)}$, $H_2O_{(l)}$ **(1 mark)**

   d. $H^+{}_{(aq)}$, $I^-{}_{(aq)}$, $H_2O_{(l)}$ **(1 mark)**

4. The solution characteristic that doesn't fit is "neutralizes bases". **(1 mark)**

5. a. hydrofluoric acid or aqueous hydrogen fluoride **(1 mark)**

   b. boric acid or aqueous hydrogen borate **(1 mark)**

   c. cesium hydroxide **(1 mark)**

   d. hydrocyanic acid or aqueous hydrogen cyanide **(1 mark)**

6. a. $3\,Ca(OH)_{2(aq)} + 2\,H_3PO_{4(aq)} \rightarrow 6\,H_2O_{(l)} + Ca_3(PO_4)_{2(aq)}$ **(1 mark)**

   b. $2\,NH_4OH_{(aq)} + H_2SO_{3(aq)} \rightarrow (NH_4)_2SO_{3(aq)} + 2\,H_2O_{(l)}$ **(1 mark)**

7. A weak acid is the best choice for treating a base burn. A strong acid would do further damage if too much were used. **(2 marks)**

8. a. $Ba(OH)_{2(s)} \rightarrow Ba^{2+}{}_{(aq)} + 2\,OH^-{}_{(aq)}$

   $[Ba^{2+}] = 0.061$ mol/L; $[OH^-] = 2 \times 0.061 = 0.122$ mol/L **(2 marks)**

b. $HNO_{3(aq)} \rightarrow H^+_{(aq)} + NO_3^-{}_{(aq)}$

$[H^+] = 0.87$ mol/L; $[NO_3^-] = 0.87$ mol/L **(2 marks)**

c. $(NH_4)_2SO_{4(s)} \rightarrow 2\ NH_4^+{}_{(aq)} + SO_4^{2-}{}_{(aq)}$

$[NH_4^+] = 2 \times 1.06 = 2.12$ mol/L; $[SO_4^{2-}] = 1.06$ mol/L **(2 marks)**

9.

$[H^+_{(aq)}]$(mol/L)	pH	Acid/Base/Neutral	Colour of Litmus
10^{-11}	11	base	blue
10^{-5}	5	acid	red
10^{-3}	3	acid	red
10^{-8}	8	base	blue

(4 marks)

10. The $[H^+_{(aq)}]$ of the solution having a pH of 4 is 10^{-4} mol/L. The $[H^+_{(aq)}]$ of the solution having a pH of 7 is 10^{-7} mol/L. The difference between the $[H^+_{(aq)}]$ of the two acids is calculated as follows:

$$\frac{10^{-4}}{10^{-7}} = 10^3 \text{ or 1000 times} \qquad \textbf{or} \qquad 7 - 4 = 3;\ 3 \text{ pH units} = 10^3 \text{ or 1000 times}$$

Therefore the $[H^+]$ is 1000 times higher in the stronger acid. **(2 marks)**

11. a. Solution #1 had to be the $C_2H_5OH_{(aq)}$. **(1 mark)**

b. Solution #3 was the $HClO_{4(aq)}$. The concentration of $H^+_{(aq)}$ in $HClO_{4(aq)}$ is 10^{-1} mol/L. **(1 mark)**

c. Solution #5 was the $H_3BO_{3(aq)}$. The concentration of $H^+_{(aq)}$ in $H_3BO_{3(aq)}$ is 10^{-5} mol/L. **(1 mark)**

d. Solution #3 or $HClO_{4(aq)}$ could best neutralize Solution #4. **(1 mark)**

e. Solution #5 or $H_3BO_{3(aq)}$ could best neutralize a base that was splashed on your skin because it is a weak acid. **(1 mark)**

12. a. Possible safety measures include the following:

- Do not touch this chemical with bare skin (caustic).
- Do not eat this chemical (poison). **(2 marks)**

b. Drain cleaner should be flushed out with a base neutralizer or water. The base neutralizer should be a weak acid (e.g., boric acid). **(1 mark)**

13. Hazardous goods response teams would have these skills:

- They would need to know the potential dangers of contact with all hazardous cargoes.
- They would need to know the correct procedure for protecting the public around any dangerous spill.
- They would need to be experts in first aid.
- They need to know how to minimize effects of exposure to dangerous chemicals. **(2 marks)**

Section 2: Gases

Key Concepts

The emphasis in this section is the development of gas laws. Along with each law, an important related topic is studied. With Boyle's law, pressure is studied; with Charles' law, temperature is studied; with Avogadro's law, the nature of the scientific process is studied; and with the Ideal Gas Law, the concepts of real and ideal gases are studied.

Teaching Suggestions

Activity 4

- During this activity, students may be interested in reading articles on the philosophy of science. There are many books that deal with this topic. Two are *Paradigms Lost* by John L. Costi and *Science: Process and Discovery* by Dennis Field.
- The following should be noted in regards to the investigation of Charles' law:

  The volume change for a 10°C temperature change is about 100 mL for a 1.5 L balloon. The balloon can be held underwater with the fingers and the error will be small as long as just the tips of the fingers are submerged.

Section 2: Assignment Answer Key (60 marks)

1. Problems in the use of hydrogen as a fuel include the following:

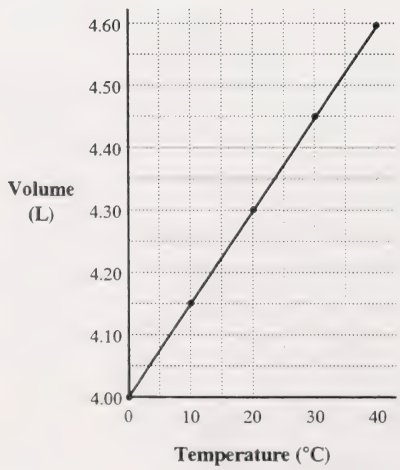
   - Better ways of storage are required.
   - Leakproof containers are needed.
   - Cheaper energy sources for making hydrogen fuel are needed. **(2 marks)**

2. The kinetic energy is indeed distributed over a larger range, but it is not evenly distributed. More particles have energy near the average than at the extremes. The corrected statement may read, "In a gas of 25°C, the kinetic energy is **unevenly** distributed over a large range." **(2 marks)**

3. a. –250°C = **23** K **(1 mark)**

   b. 450 K = **177**°C **(1 mark)**

4. a. **Graph of Temperature vs Volume**



(3 marks)

   b. The graph illustrates Charles' law. **(1 mark)**

   c. At least two points must be used. The temperature must be changed to K and $\frac{v}{T}$ ratios completed. $\frac{v}{T} \approx 0.0147$ = a constant.

Temperature (°C)	0	10	20	30	40
(K)	**273**	**283**	**293**	**303**	**313**
Volume (L)	4.00	4.15	4.29	4.44	4.59
$\frac{v}{T}\ \frac{(L)}{(K)}$	**0.0147**	**0.0147**	**0.0146**	**0.0147**	**0.0147**

$$\frac{4.00\ L}{273\ K} = \frac{4.15\ L}{283\ K} = \frac{4.29\ L}{293\ K} = \frac{4.44\ L}{303\ K} = \frac{4.59\ L}{313\ K}$$ **(3 marks)**

5. a. The volume would be determined using Avogadro's theory.

1 mol reactant → 2 mol products

$$\frac{v_1}{n_1} = \frac{v_2}{n_2}$$
$$\frac{150\text{ L}}{1\text{ mL}} = \frac{v_2}{2\text{ mL}}$$
$$v_2 = \frac{150\text{ L}(2\text{ mL})}{1\text{ mL}}$$
$$v_2 = 300\text{ L}$$

The final volume of products is 300 L. **(2 marks)**

b. This example illustrates Avogadro's theory. **(1 mark)**

6. 100 kPa + 14 kPa = 114 kPa

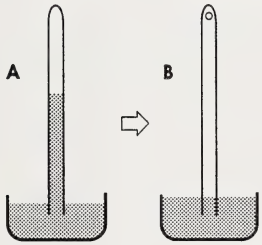
↑

Standard Ambient Pressure

The pressure of the gas sample is 114 kPa. **(1 mark)**

7. Pressure is caused by the collision of gas particles against the sides of a container. When more particles hit the sides of the container pressure is increased. When fewer particles hit the sides of the container pressure decreases. **(2 marks)**

8. a.



(1 mark)

b. The pressure inside the barometer tube would be the same as the pressure outside because the atmosphere is pushing on both surfaces. **(2 marks)**

9. You can increase the average kinetic energy in a glass of water by increasing its temperature (heat it). **(1 mark)**

10. a.

$$p_1v_1 = p_2v_2$$
$$91\text{ kPa}(2.0\text{ L}) = 20\text{ kPa}(v_2)$$
$$v_2 = \frac{91\text{ kPa}(2.0\text{ L})}{20\text{ kPa}}$$
$$v_2 = 9.1\text{ L}$$

The new volume is 9.1 L. **(3 marks)**

b.

$$\frac{v_1}{T_1} = \frac{v_2}{T_2}$$
$$\frac{10.0\text{ L}}{233\text{ K}} = \frac{v_2}{348\text{ K}}$$
$$v_2 = \frac{10.0\text{ L}(348\text{ K})}{233\text{ K}}$$
$$v_2 = 14.9\text{ L}$$

The new volume is 14.9 L. **(3 marks)**

11.

$$pv = nRT$$
$$n = \frac{pv}{RT}$$
$$n = \frac{101.3\text{ kPa}(56.0\text{ L})}{8.314\ \frac{\text{kPa}\bullet\text{L}}{\text{mol}\bullet\text{K}}(273\text{ K})}$$
$$n = 2.50\text{ mol}$$

There would be 2.50 mol. **(3 marks)**

12. a. Real gases behave as ideal gases under conditions of high temperature and low pressure. **(2 marks)**

b. Under these conditions real gases are furthest away from each other; attractions and the taking-up of volume is neglible. **(2 marks)**

13.
$$\frac{p_1v_1}{T_1} = \frac{p_2v_2}{T_2}$$
$$\frac{110\text{ kPa }(7.0\text{ L})}{253\text{ K}} = \frac{p_2(11.0\text{ L})}{318\text{ K}}$$
$$p_2 = \frac{110\text{ kPa }(7.0\text{ L})\ 318\text{ K}}{253\text{ K }(11.0\text{ L})}$$
$p_2 = 88.0$ kPa The new pressure would be 88.0 kPa. **(3 marks)**

14. a. You would need to have conflicting evidence to throw out the theory. **(1 mark)**

b. A new theory would be proposed. **(1 mark)**

15.
$$n = \frac{m}{M}$$
$$= \frac{36.0\text{ g}}{46.01\text{ g/mol}}$$
$$= 0.782\text{ mol }NO_2$$
(**or** $n = 36.0\text{ g}\left(\frac{1\text{ mol}}{46.01\text{ g}}\right)$)

$$pv = nRT$$
$$v = \frac{nRT}{p}$$
$$v = \frac{0.782\text{ mL}\left(8.314\ \frac{\text{kPa}\bullet\text{L}}{\text{mol}\bullet\text{K}}\right)298\text{ K}}{100\text{ kPa}}$$
$v = 19.4$ L The volume occupied would be 19.4 L. **(3 marks)**

16.
$$pv = nRT$$
$$n = \frac{pv}{RT}$$
$$n = \frac{101.3\text{ kPa }(1.0\text{ L})}{8.314\frac{\text{kPa}\bullet\text{L}}{\text{mol}\bullet\text{K}}(273\text{ K})}$$
$$n = 0.0446\text{ mol}$$
$$n = \frac{m}{M}$$
$$M = \frac{m}{n}$$
$$M = \frac{1.43\text{ g}}{0.0446\text{ mol}}$$
$$M = 32.1\text{ g/mol }(32.0)$$
This molar mass indicates the gas would probably be oxygen. **(3 marks)**

17. a.
$$pv = nRT$$
$$pv = \frac{m}{M}RT$$
$$M = \frac{mRT}{pv}$$
$$M = \frac{(742.20\text{ g} - 741.12\text{ g})\left(8.314\frac{\text{kPa}\bullet\text{L}}{\text{mol}\bullet\text{K}}\right)295\text{ K}}{97.9\text{ kPa }(1.414\text{ L})}$$
$M = 19.1$ g/mol The molar mass of neon is 19.1 g/mol. **(3 marks)**

b. The answer is too small. The error could be accounted for by a thermometer reading too low (i.) or a graduated cylinder reading too high (iii.). **(2 marks)**

c. The following is a possible calculation in determining what pressure would be if you had the correct molar mass:

$$p = \frac{mRT}{Mv}$$

$$p = \frac{1.08\ \text{g}\left(8.314\frac{\text{kPa} \bullet \text{L}}{\text{mol} \bullet \text{K}}\right)295\ \text{K}}{20.17\ \text{g/mol}\ (1.414\ \text{L})}$$

$p = 92.9$ kPa The lower pressure gives a better answer. **(3 marks)**

18. a. The student did not confirm Boyle's law. If Boyle's law had been confirmed, the product of $p \times v$ should have been near constant (constant within 5% error). **(2 marks)**

b. The student failed to take into account three factors:

- the force applied by the books, which involves the books' masses and gravity – $F = m \times g$
- the surface area of the syringe plunger which pushes on the air
- initial atmospheric pressure of the air **(3 marks)**

Module 3: Quantitative Relationships

Overview

In this module, students review and expand their knowledge of chemical equations and the mole concept. This knowledge is combined with new concepts so that the students are able to do stoichiometric calculations. Students then perform experiments to test the validity of assumptions contained in the stoichiometric methods. Students will demonstrate skills in using a balance to collect data for stoichiometric experiments and in using a calculator to perform stoichiometric calculations related to experiments. Finally, students consider STS connections as they examine how the knowledge of stoichiometry is used in technological industries.

MODULE 3: QUANTITATIVE RELATIONSHIPS

Section 1: Introduction to Stoichiometry

- Equations and Mole Ratios Review
- Definition of Stoichiometry
- Testing the Stoichiometric Method

Section 2: Applications of Stoichiometry

- Gas Stoichiometry
- Solution Stoichiometry
- Stoichiometry in Industry

Evaluation

The evaluation of this module will be based on two assignments:

Section 1 Assignment	**50 marks**
Section 2 Assignment	**50 marks**
TOTAL	**100 marks**

Materials and Equipment

The following is a list of materials necessary for completing the investigations and activities in Module 3. Amounts stated represent requirements per student.

Section 1: Activity 3

Investigation 7.3: Testing the Stoichiometric Method

- 2.00 g $Sr(NO_3)_{2(s)}$
- distilled water
- pan balance
- funnel
- stirring rod
- clamps
- 2.56 g $CuSO_4 \bullet 5\ H_2O_{(s)}$
- laboratory scoop
- filter paper
- beakers
- retort stand

Section 2: Activity 1

Investigation 7.4: The Universal Gas Constant

See pages 178-179 of *Nelson Chemistry* for a list of materials.

Additional Resources

Daintith, John, ed. 1988. *Dictionary of Chemistry*. New York: Facts on File Publications.

Masletta, Joseph A. 1989. *Chemistry the Easy Way*. Hauppauge, New York: Barron's Education Series.

Newton, David E. 1991. *Consumer Chemistry Projects for Young Scientists*. New York: Franlin Watts.

Wilbraham, A.C., D.D. Staley, et al. 1993. *Addision-Wesley Chemistry*. 3d ed. Don Mills, Ontario: Addison-Wesley Publishing Company, Inc.

Possible Media

Videos

Chemical Equilibrium Series. (1984) (ACCESS Network)
Includes a segment on The Haber Process.

The Mole Concept Series. (1983) (ACCESS Network)
Includes segments on Gas Volumes, The Mole, Relative Atomic Mass, and Relative Mass.

World of Chemistry Series. (1988) Annenberg/CPB Project with Raold Hoffmann, Magic Lantern Communications.
Includes segments on Chemistry, Chemistry and the Environment, and The Mole.

Section 1: Introduction to Stoichiometry

Key Concepts

In this section students review the concept of the mole and how chemists use the mole concept to deal with a large number of particles. Students also review balancing chemical equations. The concepts are fundamental to stoichiometry, the term used to describe the quantitative relationships given in chemical equations. Students learn to predict quantities of reactants and products in some chemical reactions using stoichiometric calculations.

Teaching Suggestions

It is absolutely fundamental that the students be able to write formulas and balance the equations in this section. The students with the entering skills will not have major difficulty once they have worked through a couple of the problems. Students facing difficulties in this section will probably need remedial work in balancing equations. More able students will work through the problems using factor analysis; weaker students will probably use the formula method. In either case, they will be able to solve the problems.

Section 1: Assignment Answer Key (50 marks)

1. a. $2\ KClO_{3(s)} \rightarrow 2\ KCl_{(s)} + 3\ O_{2(g)}$ **(3 marks)**

   b. $Al_2(SO_4)_{3(aq)} + 3\ Pb(NO_3)_{2(aq)} \rightarrow 2\ Al(NO_3)_{3(aq)} + 3\ PbSO_{4(s)}$ **(3 marks)**

2. Errors in the given solution include the following:

   - The equation is not balanced correctly. There should be just $1\ H_2O$, not $2\ H_2O$.
   - The last calculation step is inverted or reversed from the way it should be – it should be $\frac{100.09\ g}{1\ mol\ CaCO_3}$.
   - The answer is wrong. It should be $20.6\ g\ CaCO_3$. **(6 marks)**

3.

	Formula Method	Factor Label (units) Method	
a.	$n = \frac{m}{M}$ $= \frac{6.28\ g}{53.50\ g/mol\ NH_4Cl}$ $= 0.117\ mol\ NH_4Cl$	$n_{(NH_4Cl)} = 6.28\ g \times \frac{1\ mol\ NH_4Cl}{53.50\ g}$ $= 0.117\ mol\ NH_4Cl$	**(2 marks)**
b.	$n = \frac{m}{M}$ $= \frac{2.5\ kg}{122.07\ g/mol\ Na_2SiO_3}$ $= 0.020\ kmol\ Na_2SiO_3$ $= 20\ mol\ Na_2SiO_3$	$n_{(Na_2SiO_3)} = 2.5\ kg \times \frac{1\ mol\ Na_2SiO_3}{122.07\ g}$ $= 0.020\ kmol\ Na_2SiO_3$ $= 20\ mol\ Na_2SiO_3$	**(2 marks)**
c.	$n = \frac{m}{M}$ $= \frac{3.16\ mg}{239.26\ g/mol\ PbS}$ $= 0.0132\ mmol\ PbS$ $= 0.0000132\ mol\ PbS$ **or** $1.32 \times 10^{-5}\ mol\ PbS$	$n_{(PbS)} = 3.16\ mg \times \frac{1\ mol\ PbS}{239.26\ g}$ $= 0.0132\ mmol\ PbS$ $= 0.0000132\ mol\ PbS$ **or** $1.32 \times 10^{-5}\ mol\ PbS$	**(2 marks)**

4. a. $\frac{2\ apples}{basket} \times 20\ baskets$ $= 40\ apples$

   $\frac{3\ oranges}{basket} \times 20\ baskets$ $= 60\ oranges$

   For making 20 baskets, you would need **40 apples** and **60 oranges**. **(2 marks)**

b. The whole number mole ratios from chemical reactions allow you to calculate any relative amount of the two chemicals being related, just as the ratio between apples and oranges allowed for a calculation of total fruit in 20 baskets. **(2 marks)**

5. One atom of solid carbon reacts with one molecule of oxygen gas to form one molecule of carbon dioxide gas. **(2 marks)**

6. $Ca_3N_{2(s)} + 6\ H_2O_{(l)} \rightarrow 2\ NH_{3(g)} + 3\ Ca(OH)_{2(s)}$

$m = ?$ 4.60 mol

148.26 g/mol

Textbook method:

$$n_{(Ca_3N_2)} = 4.60\ \cancel{mol\ NH_3} \times \frac{1\ mol\ Ca_3N_2}{2\ \cancel{mol\ NH_3}}$$

$$= 2.30\ mol\ Ca_3N_2$$

$$m_{(Ca_3N_2)} = 2.30\ \cancel{mol\ Ca_3N_2} \times \frac{148.26\ g}{1\ \cancel{mol\ Ca_3N_2}}$$

$$= 341\ g$$

One-line method:

$$m_{(Ca_3N_2)} = 4.60\ \cancel{mol\ NH_3} \times \frac{1\ \cancel{mol\ Ca_3N_2}}{2\ \cancel{mol\ NH_3}} \times \frac{148.26\ g}{1\ \cancel{mol\ Ca_3N_2}}$$

$$= 341\ g$$

The mass of calcium nitride required is **341 g**. **(6 marks)**

7. $3\ Mg_{(s)} + 2\ H_3PO_{4(aq)} \rightarrow Mg_3(PO_4)_{2(s)} + 3\ H_{2(g)}$

$m = ?$ 50.0 g

24.31 g/mol 98.00 g/mol

Textbook method:

$$n_{(H_3PO_4)} = 50.0\ \cancel{g\ H_3PO_4} \times \frac{1\ mol\ H_3PO_4}{98.00\ \cancel{g\ H_3PO_4}}$$

$$= 0.510\ mol\ H_3PO_4$$

$$n_{(Mg)} = 0.510\ \cancel{mol\ H_3PO_4} \times \frac{3\ mol\ Mg}{2\ \cancel{mol\ H_3PO_4}}$$

$$= 0.765\ mol\ Mg$$

$$m_{(Mg)} = 0.765\ \cancel{mol\ Mg} \times \frac{24.31\ g}{1\ \cancel{mol\ Mg}}$$

$$= 18.6\ g$$

One-line method:

$$m_{(Mg)} = 50.0\ \cancel{g\ H_3PO_4} \times \frac{1\ \cancel{mol\ H_3PO_4}}{98.00\ \cancel{g\ H_3PO_4}} \times \frac{3\ \cancel{mol\ Mg}}{2\ \cancel{mol\ H_3PO_4}} \times \frac{24.31\ g}{1\ \cancel{mol\ Mg}}$$

$$= 18.6\ g$$

The mass of magnesium metal that will react is **18.6 g**. **(7 marks)**

8. a. The prediction may be shown as follows:

$$Cu_s + 2\,AgNO_{3(aq)} \rightarrow 2\,Ag_{(s)} + Cu(NO_3)_{2(aq)}$$

5.00 g	$m = ?$
63.55 g/mol	107.87 g/mol

$$m_{(Ag)} = 5.00\,\cancel{g\ Cu} \times \frac{1\ \cancel{mol\ Cu}}{63.55\,\cancel{g\ Cu}} \times \frac{2\ \cancel{mol\ Ag}}{1\ \cancel{mol\ Cu}} \times \frac{107.87\ g}{1\ \cancel{mol\ Ag}}$$
$$= 17.0\ g$$

The prediction is that 17.0 g Ag will be precipitated. **(5 marks)**

b. The precipitate was silver $\left(Ag_{(s)}\right)$. **(2 marks)**

c. The percent difference is greater than the 10% acceptable level. This could mean that the experimental design is flawed, or some significant errors occurred in the performance of the investigation.

Possible sources of error include the following:

- The mass of filter paper was not measured.
- The mass of filter paper was not recorded.
- The mass was not subtracted from the total mass of precipitate plus filter paper.

Assuming the mass of the filter paper was similar to other investigations done in this module (about 0.95 g) the calculations would be the following:

mass of precipitate and filter paper =	19.07 g
− mass of filter paper =	0.95 g
mass of precipitate =	18.12 g

The value for the precipitate mass is now within a 10% difference. However, the value is still higher than expected.

- Inadequate drying of the precipitate could cause a higher mass.
- If the precipitate hadn't been rinsed properly, excess $AgNO_{3(s)}$ and $Cu(NO_3)_{2(s)}$ could contribute to the extra mass recorded.

Based on the errors made in performing the investigation, the experimental design should not be changed until the investigation is performed again, correcting the identified errors. Then, if the percent difference is greater than 10%, the design may have to be re-evaluated. **(6 marks)**

Section 2: Applications of Stoichiometry

Key Concepts

In this section, students learn to deal with gas stoichiometry and solution stoichiometry. This provides a broader range of strategies to students when combined with their prior knowledge of gravimetric stoichiometry. After some practice with each of the types of problems, the students consider several examples from industrial processes. The Haber-Bosch process has been used in several examples in both sections of this module. Students also do a problem relating to the Down's Cell. Finally, students develop an understanding of the Solvay process by doing a series of textbook questions.

Teaching Suggestions

- Extreme caution must be used with the laboratory investigation in this section. The student may repeat the experiment to gain familiarity with the technique and to obtain results close to the accepted value.
- There may be an opportunity in this section to do a field trip to a facility such as a water treatment plant so that the student may view an industrial application of stoichiometry.

Section 2: Assignment Answer Key (50 marks)

1. a. D b. B c. A d. C **(4 marks)**

2. The two common steps are the following:

   - Write a balanced chemical equation.
   - Calculate moles required using a mole ratio. **(2 marks)**

3. a. The following are the steps you would follow for solving the problem:

   - Step 1 – Write a balanced chemical equation.
   - Step 2 – Find the moles of $O_{2(g)}$ from the given volume, using the Ideal Gas Law.
   - Step 3 – Find moles of water from moles of oxygen using the mole ratio from the equation.
   - Step 4 – Find the mass of water from moles of water using the molar mass of water. **(4 marks)**

   b.

$2\ H_{2(g)}$	$+\ O_{2(g)}$	$\rightarrow$	$2\ H_2O_{(g)\ or\ (l)}$
	25.2 L		m = ?
	23.2 °C		18.02 g/mol
	125 kPa		

Textbook method:

$$n_{(O_2)} = \frac{pv}{RT} = \frac{125\ \cancel{kPa}\ (25.2\ \cancel{L})}{8.31\ \frac{\cancel{kPa} \bullet \cancel{L}}{mol \bullet \cancel{K}}\ (296.2\ \cancel{K})} = 1.28\ mol\ O_2$$

$$n_{(H_2O)} = 1.28\ \cancel{mol\ O_2} \times \frac{2\ mol\ H_2O}{1\ \cancel{mol\ O_2}} = 2.56\ mol\ H_2O$$

$$m_{(H_2O)} = 2.56\ \cancel{mol\ H_2O} \times \frac{18.02\ g}{1\ \cancel{mol\ H_2O}} = 46.1\ g\ H_2O$$

The mass of water produced is **46.1 g**. **(5 marks)**

4.

$2\ C_8H_{18(l)}$	$+\ 25\ O_{2(g)}$	$\rightarrow$	$16\ CO_{2(g)}$	$+\ 18\ H_2O_{(g)}$
1.000 g			v = ? (SATP)	
114.26 g/mol			24.8 L/mol	

One-line method:

$$v_{(CO_2)} = 1.000\ \cancel{g\ C_8H_{18}} \times \frac{1\ \cancel{mol\ C_8H_{18}}}{114.26\ \cancel{g\ C_8H_{18}}} \times \frac{16\ \cancel{mol\ CO_2}}{2\ \cancel{mol\ C_8H_{18}}} \times \frac{24.8\ L}{1\ \cancel{mol\ CO_2}} = 1.74\ L$$

Textbook method:

$$n_{(C_8H_{18})} = 1.000\ \cancel{g\ C_8H_{18}} \times \frac{1\ mol\ C_8H_{18}}{114.26\ \cancel{g\ C_8H_{18}}}$$
$$= 0.00875\ mol\ C_8H_{18}$$

$$n_{(CO_2)} = 0.00875\ \cancel{mol\ C_8H_{18}} \times \frac{16\ mol\ CO_2}{2\ \cancel{mol\ C_8H_{18}}}$$
$$= 0.0700\ mol\ CO_2$$

$$v_{(CO_2)} = 0.0700\ \cancel{mol\ CO_2} \times \frac{24.8\ L}{1\ \cancel{mol\ CO_2}}$$
$$= 1.74\ L$$

The volume of CO_2 produced is **1.74 L**. **(5 marks)**

5. $2\ Al(OH)_{3(s)} + 6\ HCl_{(aq)} \rightarrow 2\ AlCl_{3(aq)} + 3\ H_2O_{(l)}$

0.920 g	$v = ?$
78.01 g/mol	0.020 mol/L

$$n_{(Al(OH)_3)} = 0.920\ \cancel{g\ Al(OH)_3} \times \frac{1\ mol\ Al(OH)_3}{78.01\ \cancel{g\ Al(OH)_3}}$$
$$= 0.0118\ mol\ Al(OH)_3$$

$$n_{(HCl)} = 0.0118\ \cancel{mol\ Al(OH)_3} \times \frac{6\ mol\ HCl}{2\ \cancel{mol\ Al(OH)_3}}$$
$$= 0.0354\ mol\ HCl$$

$$v_{(HCl)} = 0.0354\ \cancel{mol\ HCl} \times \frac{1\ L}{0.020\ \cancel{mol\ HCl}}$$
$$= 1.77\ L$$

The volume of HCl that can be neutralized is **1.77 L**. **(5 marks)**

6. $Cu_{(s)} + 4\ HNO_{3(aq)} \rightarrow NO_{2(g)} + 2\ Cu(NO_3)_{2(aq)} + 2\ H_2O_{(l)}$

95.2 mL	$v = ?$
0.115 mol/L	20.0°C
	108 kPa

$$n_{(HNO_3)} = 0.0952\ \cancel{L} \times \frac{0.115\ mol\ HNO_3}{\cancel{L}}$$
$$= 0.0109\ mol\ HNO_3$$

$$n_{(NO_2)} = 0.0109\ \cancel{mol\ HNO_3} \times \frac{1\ mol\ NO_2}{4\ \cancel{mol\ HNO_3}}$$
$$= 0.00274\ mol\ NO_2$$

$$v_{(NO_2)} = \frac{nRT}{p}$$
$$= \frac{0.00274\ \cancel{mol}\left(8.31\ \frac{\cancel{kPa} \bullet L}{\cancel{mol} \bullet \cancel{K}}\right) 293\ \cancel{K}}{108\ \cancel{kPa}}$$
$$= 0.0617\ L$$

or

61.7 mL

The volume of NO_2 that would be produced is **61.7 mL**. **(5 marks)**

7. a. The prediction may be shown as follows:

$2\ H_2O_{2(l)}$	$\rightarrow$	$O_{2(g)} + 2\ H_2O_{(l)}$
28.0 mL		$v = ?$
0.0880 mol/L		19.0°C
		101.2 kPa

$$n_{(H_2O_2)} = 0.0280\cancel{L} \times \frac{0.0880\ \text{mol}\ H_2O_2}{\cancel{L}}$$
$$= 0.00246\ \text{mol}\ H_2O_2$$

$$n_{(O_2)} = 0.00246\ \cancel{\text{mol}\ H_2O_2} \times \frac{1\ \text{mol}\ O_2}{2\ \cancel{\text{mol}\ H_2O_2}}$$
$$= 0.00123\ \text{mol}\ O_2$$

$$v_{(O_2)} = \frac{nRT}{p}$$
$$= \frac{0.00123\ \cancel{\text{mol}}\left(8.31\ \frac{\cancel{\text{kPa}} \bullet \text{L}}{\cancel{\text{mol}} \bullet \cancel{\text{K}}}\right)(292\ \cancel{\text{K}})}{101.2\ \cancel{\text{kPa}}}$$
$$= 0.0295\ \text{L}$$
$$= 29.5\ \text{mL}$$

The prediction is that **29.5 mL** O_2 will be produced. **(4 marks)**

b. The evidence may be shown as follows:

volume of H_2O_2 (L)	28.0
temperature of room (°C)	19.0
barometric pressure (kPa)	101.2
initial volume in burette (mL)	42.8
final volume in burette (mL)	15.0

(2 marks)

c. They waited so that all parts of the apparatus came to room temperature. **(1 mark)**

d. The equal water levels mean equal pressure on all parts, which is equal to the air pressure on the system. Therefore the pressure on the $O_{2(g)}$ is 101.2 kPa. **(2 marks)**

e. The data may be analysed as follows:

initial volume in burette = 42.8 mL
− final volume in burette = 15.0 mL
volume of gas collected = 27.8 mL

The gas collected was predicted to be oxygen. **(1 mark)**

f. The following is a sample evaluation:

predicted value for volume of O_2 = 29.5 mL
experimental value for volume of O_2 = 27.8 mL

$$\%\ \text{difference} = \frac{|27.8\ \text{mL} - 29.5\ \text{mL}|}{|29.5\ \text{mL}|} \times 100$$
$$= 5.76\%$$

The experimental design is judged to be acceptable because the percent difference was less than 10%. The design seems to have adequately confirmed the stoichiometric method. Care seems to have been taken in controlling variables.

Possible sources of error include the following:

- The pressure could have been better controlled with using their own barometer. They could have then seen changes in pressure that may have occurred.
- Some hydrogen peroxide may have started decomposing on its own, which would give a smaller value for the $O_{2(g)}$ produced.
- Some $O_{2(g)}$ may have been lost through leaks in the system. **(4 marks)**

8. Answers will vary. Here is a sample answer of where stoichiometry has been applied to industrial processes.

Haber-Bosch Process

$$N_{2(g)} + 3\,H_{2(g)} \rightarrow 2\,NH_{3(g)}$$

The Haber-Bosch process produces ammonia that can be used as a fertilizer itself or that can be part of further processing to produce other fertilizers. Stoichiometry is very useful in predicting how much nitrogen and hydrogen gas are needed to produce desired amounts of ammonia. Since factors such as temperature and pressure are involved in processing, stoichiometry may be able to point out when adjustments to these variables are required.

The main factor that influences the amount of product produced is consumer demand. Society controls how desirable fertilizers are, which then sets production values. **(6 marks)**

Module 4: Quantitative Analysis

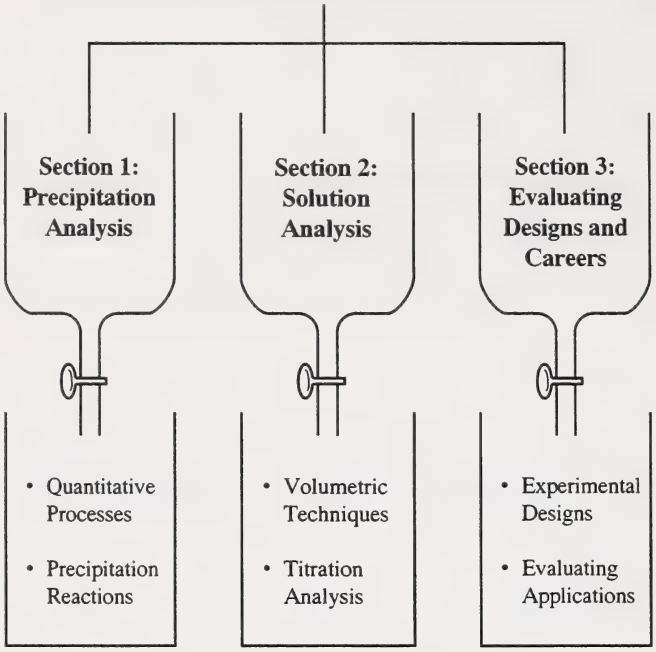
Overview

One emphasis of this module is the quantitative analysis aspect of analytical chemistry. The module also looks at how these analysis principles are applied to technology and everyday life. Some experimental designs related to quantitative analysis and their usefulness are also examined.

Students are asked to perform investigations which attempt to teach them techniques used in quantitative analysis. The students are then shown how these techniques are applied to technology. The investigations performed require simple equipment.

This module specifically examines stoichiometry of precipitation reactions and volumetric titrations. Answers are provided for most exercises in the appendix of the module booklet. The students should submit their enrichment activities to their learning facilitator for confirmation of the enrichment assignment.

MODULE 4: QUANTITATIVE ANALYSIS



Evaluation

The evaluation of this module will be based on three assignments:

Section 1 Assignment	**40 marks**
Section 2 Assignment	**40 marks**
Section 3 Assignment	**20 marks**
TOTAL	**100 marks**

Materials and Equipment

The following is a list of materials necessary for completing the investigations and activities in Module 4. Amounts stated represent requirements per student.

Section 1: Activity 2

Investigation 7.1: Analysis of Sodium Carbonate Solution

- 50 mL of 0.10 mol/L Na_2CO_3 solution
- 60 mL of 0.10 mol/L $CaCl_2$ solution
- filter paper
- funnel stand with clamp
- watch glass
- graph paper
- (3) 250 mL beakers
- stirring rod
- funnel
- wash bottle (with distilled water)
- balance

Section 2: Activity 2

Investigation 7.7: Titration Analysis of Hydrochloric Acid

See page 192 in *Nelson Chemistry* for a complete list of necessary materials.

- solid sodium carbonate
- wash bottle (with distilled water)
- stirring rod
- 250 mL beaker
- 0.10 mol/L $HCl_{(aq)}$ solution (100 mL)
- buret stand with clamp
- 100 mL graduated cylinder

Additional Resources

_____. February 1992 Supplement. *Chemical Engineering*. New York, NY: McGraw-Hill, Inc.

Hall, James F. *Experimental Chemistry*. 2d ed. Lexington, MA: D.C. Heath and Company.

Tietz, Norbert W., ed. 1987. *Fundamentals of Clinical Chemistry*. 3d ed. Philadelphia, PA: W.B. Saunders Company.

Possible Media

Videos

Choosing Science (Senior High Science Series). (1990) (ACCESS Network – VC302209)

Laser Videodiscs

Cosmic Chemistry. (1992) New Jersey: Optical Data Corporation, New Jersey.

Section 1: Precipitation Analysis

Key Concepts

This section emphasizes gravimetric reactions stoichiometry applied to quantitative analysis. The concept of limiting reagents and excess reagents is explained briefly, then examples of the concept's applications to industry are looked at.

Teaching Suggestions

- Students will find Lab Exercise 7A easier if a brief explanation of reference graphs is given before they start the exercise.

  It might be helpful if a similar type of graph unrelated to this exercise is shown on the overhead and its purpose explained. The teacher can then review how to plot the graph.

- A field trip to a hydrogen processing plant could be organized.

- Students may require extra guidance for Investigation 7.1: Analysis of Sodium Carbonate Solution in Activity 2.

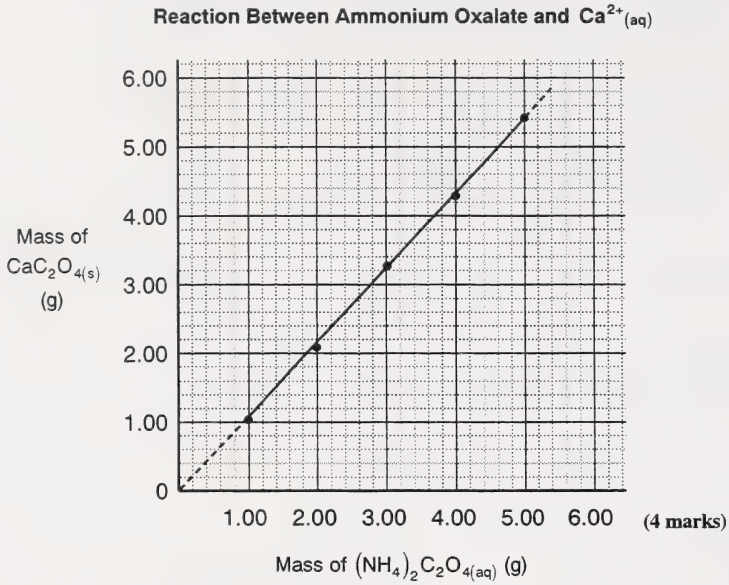
  – Demonstrate folding filter paper.
  – Remind students to read page 534 in *Nelson Chemistry,* Appendix C – filtration techniques.

Section 1: Assignment Answer Key (40 marks)

1. a. The procedure to determine the blood $Ca^{2+}{}_{(aq)}$ concentration is as follows:

- Add ammonium oxalate to the sample until no cloudiness appears and no more precipitate forms.
- Record the mass of a filter paper.
- Filter the sample.
- Dry the precipitate on a watch glass.
- Record the mass of the precipitate and filter paper. **(5 marks)**

b.



(4 marks)

c. The responding variable is the mass of precipitate, calcium oxalate, CaC_2O_4. **(1 mark)**

d. The manipulated variable is the mass of ammonium oxalate, $(NH_4)_2C_2O_4$. **(1 mark)**

e. Since the mass of precipitate was 0.50 g (1.49 g – 0.99 g), the mass of $(NH_4)_2C_2O_4$ needed is 0.45 g (using the graph). **(1 mark)**

f. The excess reagent for making all the $Ca^{2+}{}_{(aq)}$ ions precipitate would be ammonium oxalate. **(1 mark)**

g. Concentration of $Ca^{2+}{}_{(aq)}$ in the 10.0 mL sample is 0.39 mol/L, calculated as follows:

$$Ca^{2+}{}_{(aq)} + (NH_4)_2C_2O_{4(s)} \rightarrow CaC_2O_{4(s)} + 2\,NH_4{}^+{}_{(aq)}$$

$$C_{(Ca^{2+})} = 0.50\,\cancel{g\ CaC_2O_4} \times \frac{1\,\cancel{mol\ CaC_2O_4}}{128.10\,\cancel{g\ CaC_2O_4}} \times \frac{1\ mol\ Ca^{2+}}{1\,\cancel{mol\ CaC_2O_4}} \times \frac{1}{0.0100\ L}$$

$$= 0.39\ mol/L\ Ca^{2+}$$

Compared with normal values, this sample has a very high calcium ion concentration. **(4 marks)**

h. Proteins and blood cells will not pass through the filter paper, thereby increasing the mass of the precipitate. **(1 mark)**

2. a. $CaSO_{4(aq)} + Na_2CO_{3(aq)} \rightarrow Na_2SO_{4(aq)} + CaCO_{3(s)}$

$$m_{(Na_2CO_3)} = \frac{55\,\cancel{L}}{1} \times \frac{0.0030\ \cancel{mol\ CaSO_4}}{1\,\cancel{L}} \times \frac{1\ \cancel{mol\ Na_2CO_3}}{1\ \cancel{mol\ CaSO_4}} \times \frac{105.99\ g}{1\ \cancel{mol\ Na_2CO_3}}$$
$$= 17\ g$$

The mass of Na_2CO_3 required is 17 g. **(4 marks)**

b. number of bath salt tablets needed $= \frac{17\ \cancel{g\ Na_2CO_3}}{1} \times \frac{1\ tablet}{6\ \cancel{g\ Na_2CO_3}}$

$= 2.8$ tablets or 3 tablets

The number of bath salt crystals needed is 2.8 or 3. **(2 marks)**

c. $3\ \cancel{tablets} \times \frac{\$0.75}{\cancel{tablet}} = \$2.25$

The cost of softening the bath water is $2.25. **(1 mark)**

d. It is not very cost efficient. It would be cheaper to install a water softener. Answers may vary, but must be justified. **(1 mark)**

3. Answers will vary, but each example should clearly state the following:

- the name of the industry
- an example from that industry tied to quantitative analysis
- an explanation of the usefulness of the prediction (increases yield, efficiency, etc.) **(9 marks)**

4. a. Determining the chemical reactions involved in waste water treatment requires **science**. **(1 mark)**

b. Reducing pollution from a car's engine requires **technology**. **(1 mark)**

c. Determining the concentration of chocolate in chocolate milk requires **science**. **(1 mark)**

d. Determining why ice cubes make pop fizz requires **science**. **(1 mark)**

e. Controlling sulphur dioxide emissions from sulphuric acid plants require **technology**. **(1 mark)**

Section 2: Solution Analysis

Key Concepts

Different units used to express concentration are the main focus of Activity 1. Titration technique as a tool for chemical analysis is the main concept dealt with in Activity 2. Students should be familiar with the concept of concentration and dilution from Module 1. This concept is expanded to show how concentration of solutions is communicated in industry and commercial products. Titration technique is then introduced to calculate the concentration of a solution.

Teaching Suggestions

- Labels from several products such as food, medicines, beverages, or cleaners can be collected and shown to the students. This will make the students aware of the fact that concentration can be expressed in several different units.
- Students will need help in problem solving. Several examples should be given and explained by breaking the problems down into steps.

- The following suggestions are specific to Investigation 7.7: Titration Analysis of Hydrochloric Acid in Activity 2.
  - Show a video or demonstrate the titration technique before students do Investigation 7.7.
  - Use water for practising using a pipet and a buret.
  - Explain how the volume used from a buret is calculated.
  - Students should be told that in industry this procedure has been modified. Burets have been replaced by machines which add measured amounts of the titrant at a time. In some cases, the endpoint is detected by an electrode which tests the conductivity of the solution in the flask.

Section 2: Assignment Answer Key (40 marks)

1. a. $m_{(CaCO_3)} = 0.500\ \cancel{L\ CaCO_3} \times \dfrac{1.00 \times 10^{-3}\ \cancel{mol\ CaCO_3}}{1\ \cancel{L\ CaCO_3}} \times \dfrac{100.09\ g}{1\ \cancel{mol\ CaCO_3}}$

$= 5.00 \times 10^{-2}\ g$

The mass of $CaCO_3$ needed to prepare the standard solution is $5.00 \times 10^{-2}\ g$. **(4 marks)**

b. The concentrations of the three diluted solutions may be calculated as follows:

- **2.00 mL sample flask:** Using the relationship $C_i v_i = C_f v_f$,

$$\frac{1.00 \times 10^{-3}\ mol}{L} \times 0.00200\ L = 0.100\ L \times C_f$$

$$C_f = 2.00 \times 10^{-5}\ mol/L$$

The concentration of solution in the 2.00 mL sample flask is 2.00×10^{-5} mol/L.

- **3.00 mL sample flask:** Using the relationship $C_i v_i = C_f v_f$,

$$\frac{1.00 \times 10^{-3}\ mol}{L} \times 0.00300\ L = 0.100\ L \times C_f$$

$$C_f = 3.00 \times 10^{-5}\ mol/L$$

The concentration of solution in the 3.00 mL sample flask is 3.00×10^{-5} mol/L.

- **4.00 mL sample flask:** Using the relationship $C_i v_i = C_f v_f$,

$$\frac{1.00 \times 10^{-3}\ mol}{L} \times 0.00400\ L = 0.100\ L \times C_f$$

$$C_f = 4.00 \times 10^{-5}\ mol/L$$

The concentration of solution in the 4.00 mL sample flask is 4.00×10^{-5} mol/L. **(6 marks)**

2. a. Yes, the wines have the same concentration of alcohol – 12% by volume. The volumes in the bottles are different, but concentration remains 12 mL/100 mL of wine. **(2 marks)**

   b. No, the amount of alcohol is not the same. Wine A has 90 mL alcohol in 750 mL. Wine B has 96 mL alcohol in 800 mL. **(3 marks)**

3. a. Average volume of $NaOH_{(aq)}$ used is $\frac{16.5\text{ mL} + 16.4\text{ mL} + 16.5\text{ mL}}{3} = 16.5\text{ mL}$

$$NaOH_{(aq)} + CH_3COOH_{(aq)} \rightarrow NaCH_3COO_{(aq)} + H_2O_{(l)}$$

$$C_{(CH_3COOH)} = 0.0165\ \cancel{\text{L NaOH}} \times \frac{0.100\ \cancel{\text{mol NaOH}}}{1\ \cancel{\text{L NaOH}}} \times \frac{1\text{ mol } CH_3COOH}{1\ \cancel{\text{mol NaOH}}} \times \frac{1}{0.0100\text{ L}}$$
$$= 0.165\text{ mol/L } CH_3COOH$$

The concentration of the acetic acid is 0.165 mol/L. **(6 marks)**

   b. Using the relationship $C_i v_i = C_f v_f$,

$$0.0100\text{ L} \times \frac{0.165\text{ mol}}{\text{L}} = \frac{0.100\text{ mol}}{\text{L}} \times v_f$$
$$v_f = 0.0165\text{ L (or 16.5 mL)}$$

The volume of diluted solution is 0.0165 L or 16.5 mL. **(3 marks)**

   c. Possible sources of error in the procedure or analysis may include the following:

   - The buret may not have been rinsed with $NaOH_{(aq)}$, thereby affecting the $NaOH_{(aq)}$ concentration.
   - Parallax errors (viewing volumes from an angle) may have been made when reading the buret or pipette.
   - The first trial reading, which is incorrect, may have been included in the average and would throw off the concentration calculation. **(3 marks)**

   d. $$C_{(CH_3COOH)} = \frac{0.165\ \cancel{\text{mol } CH_3COOH}}{\text{L}} \times \frac{60.06\text{ g}}{1\ \cancel{\text{mol } CH_3COOH}}$$
$$= 9.91\text{ g/L}$$

The concentration of the acetic acid in mass per volume is 9.91 g/L. **(3 marks)**

4. a. The new concentration of the juice in percent by volume is $\frac{1\text{ can (juice)}}{4\text{ cans (juice + 3 cans water)}} \times 100\% = 25\%$ by volume.

(2 marks)

   b. The concentration of vitamin C $(C_6H_9O_6)$ in mol/L is 0.00199 mol/L. The calculations are as follows:

500 mg = 0.500 g

$$C_{(C_6H_9O_6)} = 0.500\ \cancel{\text{g vitamin C}} \times \frac{1\text{ mol vitamin C}}{177.15\ \cancel{\text{g vitamin C}}} \times \frac{1}{1.420\text{ L}}$$
$$= 0.00199\text{ mol/L vitamin C}$$

To calculate the concentration in mass per volume,

$$500 \text{ mg vitamin C} \times \frac{1}{1420 \text{ mL}}$$
$$= 0.352 \text{ mg/mL}$$

The concentration of vitamin C in mass per volume is 0.352 mg/mL. **(4 marks)**

c. $0.352 \text{ mg/mL} \times 100 \text{ mL}$
$= 35.2 \text{ mg}$

You consumed 35.2 mg of vitamin C. **(2 marks)**

d. The concentration of the juice in the glass is the same as in the pitcher. It is the same juice in both containers.

The amount of juice in the glass is $\frac{200 \text{ mL}}{1420 \text{ mL}} = 0.141$ or 14.1% of the amount of juice in the pitcher. **(2 marks)**

Section 3: Evaluating Designs and Careers

Key Concepts

This section emphasizes that there are different procedures that can be used to solve the same problem. The best design is the one that fits the required criteria as much as possible. The difference between procedural designs and analytical techniques is explained.

References to chemistry and science-related careers is made and the need for an adequate math and science background is reinforced through a career profile and a video.

Teaching Suggestions

- Evaluation designs can be turned into a cooperative lesson where each group works with the same problem and justifies why a particular procedure was chosen as the best design.
- Designs from other subject areas can be given as well.
- Instead of giving them the criteria, students can be asked to brainstorm in groups, and come up with the criteria. The class could then compare suggestions from each group.

Section 3: Assignment Answer Key (20 marks)

1. a. Answers may vary. The flaws in the design include the following:

- Only one trial was performed. More than one trial would give more reliable results.
- The solution (wash) produced after rinsing the remaining magnesium should not be discarded. It may contain some dissolved magnesium chloride.
- The mass of the empty evaporating dish should be recorded before pouring the solution onto the dish.
- If a ratio involving magnesium is required, the magnesium needed to be completely reacted. **(3 marks)**

b. The limiting reagent is hydrochloric acid. Since some magnesium remains, it indicates that not enough acid was added to consume all of the magnesium. **(2 marks)**

c. The calculations needed are the following:

- Find the mass of magnesium used in the reaction.
- Find the mass of magnesium chloride produced.
- Calculate the moles of magnesium which reacted with $HCl_{(aq)}$.
- Calculate the moles of magnesium chloride produced.
- Find the ratio of $\frac{\text{moles of magnesium}}{\text{moles of magnesium chloride}}$. **(5 marks)**

2. The flaws in the various designs may be identified as follows:

a. Alcohol will evaporate and no solute will crystallize. **(1 mark)**

b. $HNO_{3(aq)} + NaOH_{(aq)} \rightarrow NaNO_{3(aq)} + H_2O_{(l)}$

Sodium nitrate produced as a result of this reaction is not a low solubility product, therefore no precipitate that can be filtered will form. **(1 mark)**

c. The acid is very weak and will not significantly react with aluminum.

or

If some gas was produced, the gas collected would not be just the gas produced from the reaction, but also (and mostly) the gas already present that makes the carbonation. **(1 mark)**

d. More pH values should be tested. The manipulated variable (the pH value) covers too narrow a range to adequately assess the range of pH values. **(1 mark)**

e. Only one type of plant should be tested, otherwise more than one variable is being tested – type of plant and type of fertilizer. **(1 mark)**

3. Possible answers include the following:

- Carolyn finds the case work appealing, trying to fit all the bits of evidence together to tell a story.
- When she finds the answer to a puzzling piece of evidence it is very rewarding.
- The variety in the job is appealing. No two days are the same. **(2 marks)**

4. Answers will vary. Possible recommendations include the following:

- Talk to several people actually in the fields Alice is interested in to get a firsthand look at what these careers involve and what educational background is needed.
- Alice should take several courses in math and the sciences, so that her background will later give her the widest range of options from which to choose.
- Be sure to take a good balance of courses, not just math and science. A well-rounded background gives the greatest opportunities later. **(3 marks)**

Module 5: Chemical Bonding

Overview

One emphasis in this module is to examine the factors that affect chemical periodicity and see how these factors can be used to predict the types of bonds that form between various atoms. Students also focus on ionic and molecular compounds, including a general discussion of intermolecular bonding and relative bond strengths. The end of this module relates the way bonding is applied to technology.

A good way to start this module is to bring in a variety of different substances (either the real substances or listed on a sheet of paper) and have the students work in small groups to develop an activity that would rank the solids according to their hardness. Avoid network solids and metals. The students should then look for similarities in the other properties of hard solids and again for the soft solids. A short discussion of possible reasons for the results could ensue, acting as an incentive and rationale for the need to learn about bonding.

MODULE 5: CHEMICAL BONDING

Section 1: The Basics of Bonds

- Patterns in Reactions
- Periodicity Revisited
- Chemical Bonds

Section 2: Ionic Bonding

- Ionic Compounds
- Ionic Compound Formation
- Ionic Models

Section 3: Molecular Bonding

- Molecular Substances
- Molecular Models

Section 4: Bond Strength and Applications

- Bond Energy and Strength
- Intermolecular Forces
- Technology and Applications

Evaluation

The evaluation of this module will be based on four assignments:

Section 1 Assignment	**30 marks**
Section 2 Assignment	**25 marks**
Section 3 Assignment	**20 marks**
Section 4 Assignment	**25 marks**
TOTAL	**100 marks**

Materials and Equipment

The following is a list of materials necessary for completing the investigations and activities in Module 5. Amounts stated represent requirements per student.

Section 1: Activity 1

Investigation 8.1: Activity Series

- 0.2 g calcium, Ca
- 0.5 cm iron, Fe
- 0.5 cm magnesium, Mg
- 20 mL of 1.0 mol/L HCl
- plastic tweezers
- 0.5 cm copper, Cu
- 0.5 cm lead, Pb
- 0.5 cm zinc, Zn
- steel wool
- safety glasses
- (6-12) 100 mm test tubes and test tube rack, **or** (6) 50 mL beakers and a watch glass, **or** 1 microtray and cover

Note: If you are doing the reaction using microtrays, the amounts required will be less. Minor changes in amounts may be needed if beakers are used.

Section 2: Activity 3

Investigation: Building an Ionic Crystal

- small, multi-coloured soft jelly candies (ju-jubes or gumdrops)
- box of toothpicks
- a few crystals of table salt, NaCl

Note: If this activity is done as a class, each student will require two colours of jelly candies, 24 candies of each colour.

Section 3: Activity 2

Investigation 8.2: Molecular Models

- a molecular models kit

Investigation 8.3: Evidence for Double Bonds

Part A

See page 223 in the textbook *Nelson Chemistry* for additional materials.

- 5 small test tubes
- test tube rack
- 10 drops cyclohexene, C_6H_{10}
- 10 drops paint thinner
- 5 drops bromine in trichlorotrifluoroethane
  or
  5 drops bromine in water
- 5 stoppers for test tubes
- 10 drops cyclohexane, C_6H_{12}
- 10 drops olive oil
- 10 drops corn oil or other light vegetable oil

Note: You may wish to substitute three other common materials for the olive oil, paint thinner, and corn oil.

Section 4: Activity 2

Investigation: Showing Molecular Polarity

- 4 polystyrene or paper cups
- large cooking pot or beaker
- 1 large sewing needle or straightened paper clip
- 75 mL water
- 75 mL light cooking oil (e.g., sunflower oil, olive oil)
- small balloon or comb
- cake pan or tray
- paper towel or rag
- 75 mL rubbing alcohol or other alcohol
- 75 mL vinegar

Additional Resources

Austin, George T. 1984. *Shreve's Chemical Process Industries*. 5th ed. Toronto: McGraw-Hill Inc.

Brinkerhoff, R.F. 1992. *One Minute Readings: Issues in Science, Technology, and Society*. Don Mills, Ontario: Addison-Wesley Publishing Company, Inc.

_____. *Chem Matters Magazine*. Robson, David P., ed. Columbus, OH: American Chemical Society.

Golob, Richard, and Eric Brus, ed. 1990. *The Almanac of Science and Technology: What's New and What's Known*. Boston: World Information Systems, Harcourt Brace Jovanovich, Inc.

Wilbraham, Anthony C., D.D. Staley, et al. 1993. *Addison-Wesley Chemistry*. 3d ed. Don Mills, Ontario: Addison-Wesley Publishing Company, Inc.

Possible Media

Videos

Electron Arrangement and Bonding Series. (1984) TV Ontario. (ACCESS Network – VC289305)
Includes segments on Electron Arrangement, How Atoms Bond, Metals and Ionic Solids, and Molecular Substances and Covalent Crystals.

World of Chemistry Series. (1988) Annenberg/CPB Project with Raold Hoffmann, Magic Lantern Communications.
Includes a segment on Chemical Bonds.

Laser Videodiscs

Cosmic Chemistry. (1992) Optical Data Corporation, New Jersey.

Section 1: The Basics of Bonding

Key Concepts

In this section the student will learn to develop an activity series and relate this to the periodicity of the periodic table. The student will then begin to examine reasons for this periodicity by reviewing the basic trends on the periodic table. These patterns will be explained by use of the octet rule and the concept of electronegativity. Electronegativity will then be used to predict whether bonds will be non-polar covalent, polar covalent, or ionic. The section will end with an analysis of how ionic and covalent compounds are significant in daily life.

Teaching Suggestions

- The teacher should stress the importance of electronegativity and the octet rule to chemical bonding. It would be useful as a review to have the students work in groups to generate lists or diagrams that show instances where the octet rule and electronegativity are crucial to an understanding of the phenomenon. Whenever possible actual samples of materials should be brought in for students to observe.

- In Activity 3, as an extension to show the significance of ionic and covalent bonding to daily life, you may divide the class in two and have one group examine the roles of ionic and covalent substances in their bodies while another group examines the characteristics of some of the synthetic materials used to repair or replace these body parts.

  A variation on this would be to have groups examine the characteristics of a certain body part (such as bone) and then compare and contrast it to the same synthetic body part (artificial bone).

Section 1: Assignment Answer Key (30 marks)

1. a. The reactivity order is based o n the metals' relative electronegativities.

Order	Metal	Reason
1	potassium	Potassium has the highest electronegativity – 0.8.
2	calcium	Calcium has the second highest electronegativity – 1.0.
3	manganese	Manganese has the third highest electronegativity – 1.5.
4	cadmium	Cadmium has the fourth highest electronegativity – 1.7.
5	tin	Tin has the fifth highest electronegativity – 1.8.
6	gold	Gold has the lowest electronegativity – 2.4.

(2 marks)

b. The student obtained the following activity series order: potassium, calcium, manganese, tin, gold, and cadmium. **(1 mark)**

c. Reasons for the possible discrepancy in the results could include the following:

- The oxide coating was not properly removed from the cadmium.
- The bubbles on the gold were due to air in the solution and not because of a reaction.
- The acid used for the cadmium was more dilute than that for the tin and gold. **(2 marks)**

2. a. b. c. **(3 marks)**

3. a. valence electrons **(1 mark)**

b. non-polar covalent bond **or** polar covalent bond **(1 mark)**

c. ionic bond **(1 mark)**

d. electronegativity **(1 mark)**

4.

Atom Combination	Type of Bond	Reason
Li or Be and Cl	ionic	A metal is being joined to a nonmetal.
B, C, O, or F and Cl	polar covalent	There is a slight difference in electronegativities between the atoms.
N and Cl	non-polar covalent	Both elements have the same electronegativities.
Ne and Cl	no bond	Neon has a complete octet.

(4 marks)

5. Because bonding is a continuum, there is no real cutoff to say when a bond is polar covalent and when the bond is ionic. This is especially true for the metalloids that have some metal and some nonmetal properties. Therefore, it depends on when the person decides the difference in electronegativity is large enough to be classified as ionic. **(2 marks)**

6. The octet rule states that all atoms have the desire to fill all of their valence orbitals. This desire becomes greater as the number of valence electrons increases. This increased desire is reflected in an increase in electronegativity as well.

A non-polar covalent bond is formed between atoms of similar electronegativities and usually with a similar number of valence electrons. An example of this is when an atom bonds to itself. Both atoms have the same number of valence electrons. Atoms with the same number of valence electrons usually form covalent bonds because each atom has close to the same desire to complete its octet.

However, as the difference between the number of valence electrons in two atoms increases, the desire for one atom to complete its octet becomes greater, while the desire for the other atom to complete its octet becomes smaller. Thus, a polar covalent bond forms. A polar covalent bond can be predicted from the periodic table by checking the differences in electronegativities of the two atoms. When the difference in the number of valence electrons is very great, an ionic bond forms because the atom with the fewest valence electrons loses them to the atom with the greater number of valence electrons so that both atoms end up with the same electron configuration as a noble gas. **(6 marks)**

7. There are many possible answers; here are several examples.

Bond Type	Substance	Functions
Non-Polar Covalent	hydrogen, H_2	• a fuel for space travel • the hydrogenation processes of margarines • the hydrocarbon cracking processes
Non-Polar Covalent	chlorine, Cl_2	• bleach production • dry-cleaning solvent • hydrochloric acid production (used in many chemical processes)
Polar Covalent	methane, CH_4	• a fuel • precursor in the production of larger hydrocarbons and polymers
Polar Covalent	ammonia, NH_3	• makes fertilizers or is a fertilizer itself • makes cleaning agents
Ionic	sodium chloride, NaCl	• enhances flavour in foods • serves many functions in the body (nerve signal transport, saline in the blood, and so on)
Ionic	silver nitrate, $AgNO_3$	• part of the development process for photographs • can act as an antibacterial agent

(6 marks)

Section 2: Ionic Bonding

Key Concepts

The main emphasis of this section is to have the students learn the basic principles of oxidation and reduction as they relate to the elements of the periodic table. After completing this section, the student should be able to explain how and why ionic compounds form, and balance ionic equations using the half-reaction method. In addition, the student should be able to explain why ionic crystals have their basic shape, relating it to an explanation of the formula unit. This is an excellent section for students to become aware of the large number of ionic substances present in their daily lives.

Teaching Suggestions

- Visual models should be brought in whenever possible to show ionic crystals. This section could be started with every student being given a small card with either *S* (strong) or *W* (weak) on it. Some can be given two or three cards of only S or only *W*. Then have each *S* student find a *W* student for each *S* card they have. When all the *S* cards and *W* cards are paired (the students should now be in groups), discuss how this relates to the formation of an ionic solid.

- For Activity 2 have students research and give a report on a particular application of oxidation and reduction reactions. They should also be able to identify these reactions; for example, galvanization, cathodic protection, rusting, and the construction of batteries.

Section 2: Assignment Answer Key (25 marks)

1. a. The chemical formula for potassium oxide is K_2O; the chemical formula for magnesium oxide is MgO. **(1 mark)**

   b. Potassium oxide is the most ionic. **(1 mark)**

   c. Potassium oxide is the most ionic because it has the greatest differences in electronegativities between its two elements. **(1 mark)**

2. Two reasons for a lower reactivity of the alkaline earth metals over the alkali metals are the following:

   - Group 2 elements generally have a slightly higher electronegativity.
   - The alkali earth metals need to lose two electrons instead of one in order to obtain a complete octet (which is not as easy).

   (2 marks)

3. a. In terms of electron transfer, when a neutral atom becomes an ion with a 2^- charge, the process of **reduction** has occurred. **(1 mark)**

   b. In a balanced oxidation-reduction reaction, a total of 15 electrons are transferred. If the anion charge is 3^-, then the cation charge is 5^+. **(1 mark)**

   c. An ionic crystal of unknown formula M_xQ_y contains 2.11×10^{20} cations of M and 4.22×10^{20} anions of Q. The formula unit is MQ_2. **(1 mark)**

4. a.
$$\begin{array}{l} 2(Ag \rightarrow Ag^+ + e^-) \\ F_2 + 2e^- \rightarrow 2F^- \\ \hline 2Ag + F_2 \rightarrow 2AgF \end{array}$$
(3 marks)

   b.
$$\begin{array}{l} 3(Cu \rightarrow Cu^{2+} + 2e^-) \\ 1(N_2 + 6e^- \rightarrow 2N^{3-}) \\ \hline 3Cu + N_2 \rightarrow Cu_3N_2 \end{array}$$
(3 marks)

   c.
$$\begin{array}{l} 4(Cr \rightarrow Cr^{3+} + 3e^-) \\ 3(O_2 + 4e^- \rightarrow 2O^{2-}) \\ \hline 4Cr + 3O_2 \rightarrow 2Cr_2O_3 \end{array}$$
(3 marks)

5. a. The order of metals from most easily oxidized to least easily oxidized is X, Z, Y. **(1 mark)**

   b. The reason for the order may be given as follows: To rank the metals, the most easily oxidized metal will corrode in each of the pairs, the second most easily oxidized metal will corrode with one of the other metals, and the least easily oxidized metal would not corrode with either of the other metals. **(1 mark)**

   c. If one of the metals was from Group 2, it would most likely be X. Since X is the most easily oxidized, it has valence electrons that are most easily removed. With the limitations given, this is most likely the Group 2 metal. Another reason is because it probably has the lowest electronegativity; therefore, it must be as far to the left of the table as possible. **(2 marks)**

6. Alkali metals are never found in pure form because they are too easily oxidized. Their electrons are very easily removed so they form compounds readily. **(1 mark)**

7. Some properties of ionic compound crystals and the reasons for these properties are listed.

   - Ionic compound crystals of different substances have unique shapes because of their unique formula units.
   - Ionic crystals are hard because of strong ionic bonding.
   - Ionic crystals do not conduct electricity well because of localized electrons.
   - Ionic crystals have high melting points because of strong ionic bonding. **(3 marks)**

Section 3: Molecular Bonding

Key Concepts

In this section the student will examine molecular compounds by learning to draw Lewis models and structural diagrams of these compounds. The student will also use these structures to explain why and how molecular compounds form. In addition, the student will use molecular models to gain insight into what happens during a chemical reaction. This will be related to what has been learned previously about chemical bonding, including the relationship between bond polarity and molecular polarity. To conclude this section, the limitations of the bonding theories studied thus far will be summarized.

Teaching Suggestions

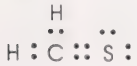
- The teacher should discuss the role trial and error plays in scientists trying to figure out the molecular structure of a compound. If related to puzzle building, the students recognize the rules for drawing structures more as guidelines to help them get started. This also helps to lower some students' frustration levels. As an opening activity to stress this idea, a Black Box experiment, where people try to guess what's inside a box without peeking, could be useful.
- Students generally need much practice drawing Lewis models. To help, constantly ask students why certain structures exist, and try to get them to look for a pattern in how they draw the structures. Some possible questions could be the following:
  - Why is this atom central?
  - Why are all the atoms with single bonds joined first?
- Have students draw Lewis models before actually doing Investigation 8.2: Molecular Models. In this way, they will better be able to transfer their knowledge of Lewis models to molecular structures.
- In Investigation 8.3: Evidence for Double Bonds, try to avoid noxious chemicals such as gasoline. Advise students to add the cyclohexene and cyclohexane in a fume hood to further minimize the odour. Make sure test tubes are stoppered when not in the fume hood.

Section 3: Assignment Answer Key (20 marks)

1. a. CI_4

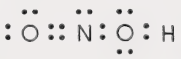
b. C_2H_6

c. H_2CS



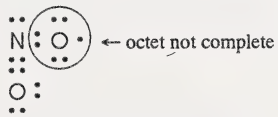
d. C_2F_2

e. HNO_2



(5 marks)

2. A person would not be able to draw a simple Lewis model of NO_2 because the oxygen in this molecule would not have a complete octet. According to the theory presented in this module, all atoms should have a complete octet. **(1 mark)**



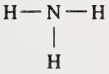
3. Molecular compounds are held together by covalent bonds. When a covalent bond forms, the electrons in the atoms are shared. Once all of the bonding electrons are used up, all the atoms have a complete octet and no more bonds will form. This creates a unit molecule.

   When an ionic compound forms, electrons are first fully transferred to form ions. Each ion can then be attracted to and surrounded by a number of ions of opposite charge. Since there are no distinct units (like molecules) that form, all the ions are bonded together to form crystals containing many ions. The ratio of cation to anion remains constant, however, and this ratio is represented by a formula unit. **(6 marks)**

4. a. three **(1 mark)** b. fluorine **(1 mark)** c. non-polar covalent **(1 mark)**

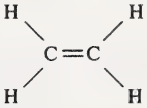
5. Nitrogen is bonded to only two atoms because it makes a single bond with fluorine and a double bond with oxygen. **(1 mark)**

6. a.

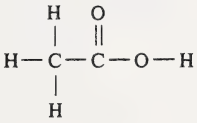


b.

c.



d.



(4 marks)

Section 4: Bond Strength and Applications

Key Concepts

In the first activity of this section, the student will relate the concepts of exothermic and endothermic to energy changes and bonds forming or breaking. These energy changes will be related to both intramolecular forces and intermolecular forces which are discussed in more detail in the second activity. The relative strengths of intermolecular forces, where they are located, and the kinds of properties they explain are discussed.

To end the module, the student will examine how science and technology work together to create new compounds such as composites and ceramics. Because of the vital role the computer plays, it will be specifically examined.

Teaching Suggestions

- To start this section, bring in a plant. Have the students explain the energy changes involved in plants. See if the students can compare the energy the plant uses to a calorie count of plant foods humans consume.
- To open Activity 2, have a bubble gum blowing contest or a challenge to see who can put the most pennies in a cup that has been filled to the brim with water.

An alternative plan could be to have a soap bubble making contest to see who can make the biggest bubbles. One recipe for soap bubbles is as follows:

- 3 parts water
- 2 parts glycerol (available at drugstores)
- 1 part dishwashing liquid

- Another Activity 2 opener is a class discussion on day-to-day concerns such as plastic wrap sticking, nonstick frying pans, or glues versus cements.

- Sometime during Activity 3 is an excellent time for a field trip to an analytical laboratory such as a water treatment plant, medical laboratory, research facility, or gas plant. An alternative would be to visit an industrial plant to see how technology is used to help build such things as composites, fibre optics, or other chemicals. If this is not feasible, having a guest lecturer speak to the class about his or her research or industry would be beneficial.

Section 4: Assignment Answer Key (25 marks)

1. The forces involved in the oxygen and sugar situations both involve the attraction of electrons by nuclei and vice versa. **(1 mark)**

2. a. Frozen orange juice melting is endothermic. **(1 mark)**

   b. Frozen juice melting an endothermic process because energy is being absorbed by the orange juice to melt. This energy is used to break the intermolecular bonds between the molecules in the solid state. **(2 marks)**

   c. The molten steel example is an exothermic reaction because energy is being lost. This energy is lost when bonds form between metal atoms in the solid steel. **(2 marks)**

3. a. Bonds are formed when steam condenses. **(1 mark)**

   b. Intramolecular forces are involved in this change because bonds are forming between water molecules, not inside water molecules. **(1 mark)**

   c. Energy is released in this process. **(1 mark)**

4. a. The order of the substances from strongest to weakest intermolecular forces is glycerol, water, and rubbing alcohol. **(1 mark)**

   b. To rank from strongest to weakest, you must know that the higher the melting point, the stronger the intermolecular forces. This is because it takes more energy to break the bonds. **(2 marks)**

5. a. ceramic b. intermolecular forces c. composites **(3 marks)**

6. The intermolecular forces holding the methanol molecules together

   - are weaker than the forces between the C and H atoms in methane
   - occur over a greater distance than between the C and H atoms in the methane molecules
   - are between the molecules rather than within them (between atoms) **(3 marks)**

7. a. Following are a few ways a computer could be used in developing a new ceramic:

   - It could run simulations or predictions.
   - It could generate three-dimensional models that are easily visualized.
   - It could help interpret data or perform numerous calculations from analytical instruments.
   - It could control, adjust, and monitor the analytical instruments.
   - It could illustrate and aid in the understanding of how the reaction to develop the ceramic is occurring. **(4 marks)**

b. Analytical instruments have helped scientists develop materials in the following ways:

- They allow scientists to better see the atoms and molecules (or develop better models of how they look). **(1 mark)**

In addition to the previous point, the answer should have **one** of the following statements.

- They allow scientists to determine the physical and chemical properties more accurately and precisely.
- Analytical instruments allow scientists to control the variables that may affect the reaction.
- Analytical instruments allow scientists to measure very small changes or concentrations effectively. **(1 mark)**

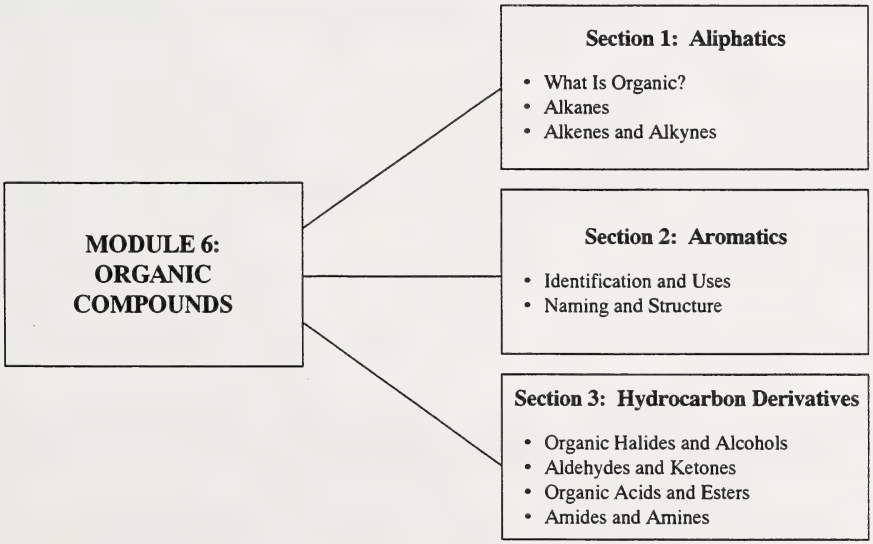
c. If technology did not continue to develop, scientific research would stagnate because there would not be ways to perform some of the experiments necessary to gain new knowledge. **(1 mark)**

Module 6: Organic Compounds

Overview

This module deals with an introduction to organic chemistry or carbon-based compounds. Section 1 essentially covers the aliphatic hydrocarbons consisting of the alkanes, alkenes, and alkynes. Section 2 considers the aromatic compounds or benzene-derived molecules. The hydrocarbon derivatives consisting of organic halides, alcohols, aldehydes, ketones, carboxylic acids, esters, amines, and amides are studied in Section 3.

The student should be able to relate various aspects of science, technology, and society in this module.



Evaluation

The evaluation of this module will be based on three assignments:

Section 1 Assignment	**40 marks**
Section 2 Assignment	**25 marks**
Section 3 Assignment	**35 marks**
TOTAL	**100 marks**

Materials and Equipment

The only materials and equipment requirement for Module 6 is a molecular model kit.

Additional Resources

_____. 1992. *Alchem 20*. Edmonton: J. M. LeBel Enterprises, Ltd.

Allinger N., et al. 1979. *Organic Chemistry*. New York: Worth Publishers, Inc.

Budavari, Susan, ed. 1989. *Merck Index*. 11th ed. Rahway, New Jersey: Merck.

Hawley, Gessner G. 1987. *The Condensed Chemical Dictionary*. 11th ed. Toronto: Van Nostrand Reinhold Co.

Kirk-Othmer. 1978. *Encyclopedia of Chemical Technology*. 3d ed. New York: Wiley.

Streitwieser, A., et al. 1985. *Introduction to Organic Chemistry*. 3d ed. New York: Macmillan Publishing Co., Inc.

_____. 1990. *The Tormont Websters Illustrated Encyclopedia Dictionary*. Montreal: Tormont Publications Inc.

Possible Media

Videos

Organic Chemistry 1 Series. (1987) TV Ontario, Box 200, Station Q, Toronto, Ontario, M4T 2T1 (416-484-2600) (ACCESS Network)
Includes Segment No. 1: Carbon the Compromiser and Segment No. 4: Fixing Fuels.

Organic Chemistry 2 Series. (1988) TV Ontario.
Includes Segment No. 4: ASA.

Petroleum: River of Energy. (1989) ACCESS Network.

Laser Videodisc

Cosmic Chemistry. (1992) Optical Data Corporation, New Jersey.

Section 1: Aliphatics

Key Concepts

The unique properties of carbon, responsible for the formation of numerous organic compounds, and its sources are introduced. Carbon bonding, common compounds, molecular structure, and nomenclature are developed and emphasized. Structural notation as well as nomenclature of alkane, alkene, and alkyne compounds are major components in the activities.

The construction of molecular models of common representative molecules is central to the laboratory activities.

Teaching Suggestions

- Consider field studies to an oil refinery, a petrochemical industry, a plastic extrusion, moulding, or manufacturing plant, or an oxyacetylene welding shop.
- Show the video *Petroleum: River of Energy* (60 min. colour) as an overview of the oil industry.
- Obtain speakers from NAIT/SAIT to investigate opportunities in the petrochemical industry and related technologies.
- Identify specific areas of student interest such as ethylene applications for further research. Develop a window display or collection of pictures or products reflecting that interest.

Section 1: Assignment Answer Key (40 marks)

1. Answers may vary but could include any three of the following:

   - the high bonding capacity of carbon (four)
   - ability of carbon to form multiple covalent bonds
   - ability of carbon to form long chain molecules
   - ability of carbon to bond to other carbons
   - ability of carbon to form isomers

   (3 marks)

2. a. As the molecules get larger in each series, the boiling points increase. This is because of the corresponding increase in intermolecular forces of attraction. **(2 marks)**

   b. $CH_3— CH_2— CH_2— CH_2— CH_3$

   pentane

   $$\begin{array}{c} CH_3 \\ | \\ CH_3— C — CH_3 \\ | \\ CH_3 \end{array}$$

   2,2-dimethylpropane

   The two molecules are quite different in shape. The cross shape of 2,2-dimethylpropane would probably not allow its molecules to pack as closely together as pentane molecules. This would result in weaker intermolecular forces and a lower boiling point. **(2 marks)**

3. The five non-cyclic isomers of C_5H_{10} include the following:

   $CH_2 = CH— CH_2— CH_2— CH_3$

   1-pentene

   $$\begin{array}{c} CH_3 \\ | \\ CH_3 — C = CH — CH_3 \end{array}$$

   2-methyl-2-butene

   $CH_3— CH = CH— CH_2— CH_3$

   2-pentene

   $$\begin{array}{c} CH_3 \\ | \\ CH_2 = C — CH_2 — CH_3 \end{array}$$

   2-methyl-1-butene

   $$\begin{array}{c} CH_3 \\ | \\ CH_2 = CH — CH — CH_3 \end{array}$$

   3-methyl-1-butene

   (5 marks)

4. a. Springs had to be used because the angles of the holes of the carbon atoms would not allow for four atoms to hold together in a ring, using sticks. **(1 mark)**

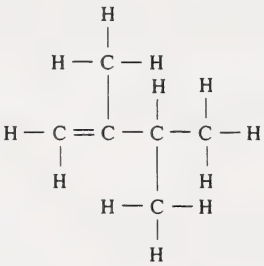
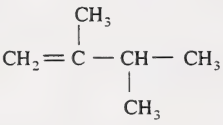
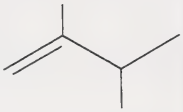
   b. The real life structure of cyclobutane may not be that stable. The bulging springs suggest that there may be stress on the bonds in real life. **(2 marks)**

5. Similarities and differences among alkanes, alkenes, and alkynes include the following:

Similarities	Differences
• They all contain carbon and hydrogen, that is, they are all hydrocarbons. • They all form homologous series. • They all use the same prefixes to denote the number of carbon atoms in chains. • They all have a main chain and can also have branches. • They are all aliphatic compounds.	• They each have a different general formula. • Alkanes are saturated, whereas alkenes are unsaturated with double bonds and alkynes are unsaturated with triple bonds. • They all have different suffixes on their names to denote the type of aliphatic compound.

(6 marks)

6.

Molecular Formula	Complete Structural Formula	Condensed Structural Diagram	Line Structural Diagram
C_6H_{12}			

(4 marks)

7. a. 3-methylpentane

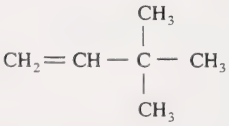
b. 2,3-dimethyl-3-hexene

c. 2-ethyl-3-methyl-1-butene

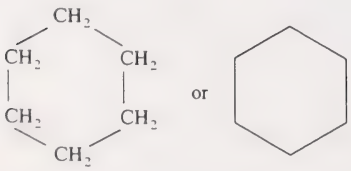
d. 3,5-diethyl-2,6-dimethyl-4-propylheptane

e. 3,5-dimethyl-3-propyl-1-octyne **(5 marks)**

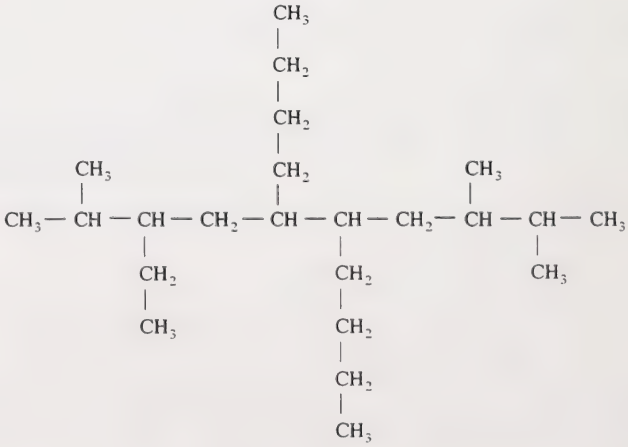
8. a. 3,3-dimethyl-1-butene



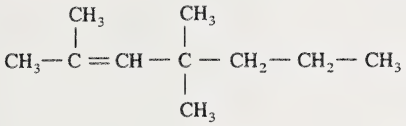
b. cyclohexane



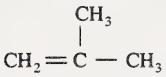
c. 5,6-dibutyl-3-ethyl-2,8,9-trimethyldecane



d. 2,4,4-trimethyl-2-heptene



e. methylpropene



(5 marks)

9.

Second Member	alkanes	alkenes	alkynes
Name	ethane	propene	propyne
Condensed Structure	$CH_3—CH_3$	$CH_3—CH=CH_2$	$CH_3—C\equiv CH$

(3 marks)

10. Ethene is used to make such products as plastic (polyethylene), polyvinyl chloride (PVC), and ethylene glycol. **(2 marks)**

Section 2: Aromatics

Key Concepts

The structure of benzene from a historical and contemporary viewpoint is explored. The compounds in which benzene is involved are examined in terms of structure and nomenclature.

Teaching Suggestions

Construct a benzene display chart using pictures or products to illustrate common aromatic compounds.

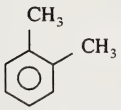
Section 2: Assignment Answer Key (25 marks)

1. Answers may vary but could include the following facts:

   - All carbon bonds in benzene are equal in length and strength, something not proposed by Kekulé.
   - Evidence shows that all six carbons in benzene are identical and are bonded to one hydrogen atom only. **(2 marks)**

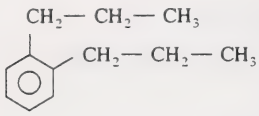
2. The original system for naming benzene compounds was the classical system. For disubstituted benzenes, prefixes were used to indicate the relative position of the substituted groups. The more recent IUPAC system, a more universal system, indicates substituted groups by number.

   Examples will vary, but should illustrate the difference in naming.

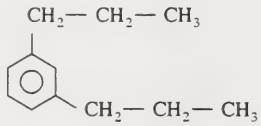


1,2-dimethylbenzene (IUPAC)
or
orthodimethylbenzene (classical)
(o-dimethylbenzene) **(4 marks)**

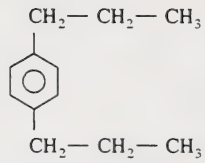
3. Three possible isomers for dipropylbenzene are the following:



1,2-dipropylbenzene
or
o-dipropylbenzene



1,3-dipropylbenzene
or
m-dipropylbenzene



1,4-dipropylbenzene
or
p-dipropylbenzene **(3 marks)**

4. a. 1-methyl-4-propylbenzene (or p-methylpropylbenzene)

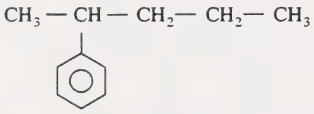
   b. 2-methyl-1-phenyl-2-butene

   c. 1-ethyl-3,5-dimethylbenzene

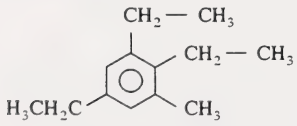
   d. 2,5-dimethyl-3-phenylhexane

   e. 4-methyl-3-phenyl-1-hexyne **(5 marks)**

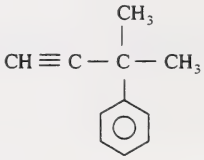
5. a. 2-phenylpentane



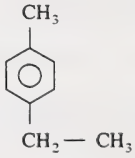
   b. 1,2,5-triethyl-3-methylbenzene



   c. 3-methyl-3-phenyl-1-butyne



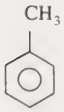
   d. p-ethyltoluene



(8 marks)

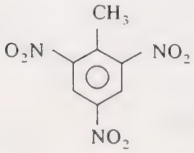
6. Examples (can be taken from Figures 6.4 and 6.5 in the module booklet) will vary. Three examples should be given.

- toluene (methylbenzene)



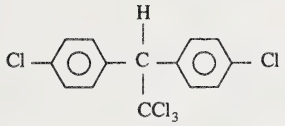
  – Toluene has a methyl group attached.
  – It is a solvent and is used in glues.

- TNT (2,4,6-trinitrotoluene)

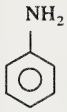


  – TNT is an explosive.
  – The NO_2 groups seem to give the molecule explosive properties.

- DDT (dichlorodiphenyltrichloroethane)
  - DDT is used as an insecticide.
  - Chlorine atoms seem to give this molecule its lethal properties.



- aniline (aminobenzene)
  - Aniline is used in perfumes.
  - The NH_2 group seems to give the molecule an odour property.



(3 marks)

Section 3: Hydrocarbon Derivatives

Key Concepts

The development and extension of organic compounds to include the various classes of hydrocarbon derivatives considers a relevant situation or experience for the learning cycle to continue.

Teaching Suggestions

- Construct a display chart using pictures or a collection of products for each hydrocarbon derivative or selected hydrocarbon derivatives to illustrate common compounds and uses.
- Obtain a speaker from AADAC or the local police to speak on the topic of alcohol abuse.

Section 3: Assignment Answer Key (35 marks)

1. A functional group gives a hydrocarbon derivative its unique chemical and physical properties. For example, the — COOH group on a carboxylic acid gives the compounds its acidic properties. **(3 marks)**

2. The elements that make up functional groups (besides C and H) are F, Cl, Br, I, N, and O. **(3 marks)**

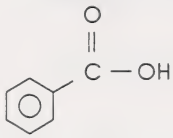
3. CFCs (chlorofluorocarbons) are organic halides used in refrigeration, air conditioning, cookware, and labware. One example is Freon 114 (1,1-dichloro-1,2,2,2-tetrafluoroethane). **(2 marks)**

4. Isomers of C_4H_8O include the following:

$CH_3-CH_2-\overset{\overset{\displaystyle O}{\|}}{C}-CH_3$	$CH_3-CH_2-CH_2-\overset{\overset{\displaystyle O}{\|}}{C}-H$
This is a ketone derivative.	This is an aldehyde derivative.

(4 marks)

5.

Compound	Derivative Type	Reason
a. 	carboxylic acid	The —COOH group identifies carboxylic acids.
b. trichloroethane	organic halide	The prefix *chloro-* identifies an organic halide.
c. $CH_3 - CH_2 - C(=O)H$	aldehyde	The $-C(=O)-H$ end identifies an aldehyde structure.
d. 2-butanone	ketone	The *-one* name ending identifies a ketone.
e. $CH_3 - CH_2 - C(=O) - NH_2$	amide	The $-C(=O)-N-$ group identifies an amide structure.

(5 marks)

6. No, it would be impossible to tell which type of derivative the compound was because many derivatives emit odours. **(2 marks)**

7.

Similarities	Differences
• Both have a carbonyl functional group. • Both emit odours. • Both have a terminal end functional group.	• Carboxylic acids exhibit acidic properties, unlike aldehydes. • Carboxylic acid functional groups also have —OH groups, unlike aldehydes. • Aldehydes are used in perfumes, whereas carboxylic acids are found in food. • Carboxylic acids exhibit strong hydrogen bonding, unlike aldehydes.

(4 marks)

8. The functional group of alcohols, the hydroxyl (— OH) group, gives alcohols relatively high boiling points. This is because the — OH group creates greater intermolecular (hydrogen) bonding that holds the molecules tighter together. **(2 marks)**

9. a. Carboxylic acids turn blue litmus red.

   b. Amines are responsible for fishlike odours.

   c. Organic halides (or aromatic compounds) make efficient insecticides.

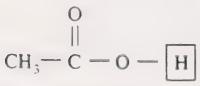
   d. Alcohols create cleaner and more efficient fuel blends.

   e. Esters give candies their flavour.

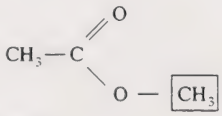
   f. Aldehydes were used at one time as a biological preserver. **(6 marks)**

10. The difference between an ester and a carboxylic acid is based on what is attached to the single bonded oxygen in the functional group. In carboxylic acids, a hydrogen bonds to the oxygen. In esters, an alkyl group bonds to the oxygen.

Examples will vary.



carboxylic acid



ester

(4 marks)

Module 7: Organic Reactions

Overview

This module focuses on simple organic reactions and looks at several applications of simple organic molecules to provide an anchoring point of relevance for the student. A comparison between living and nonliving systems is drawn to illustrate the changes that an organism must make to utilize organic reactions. Finally the student looks at careers related to organic chemistry and the positive and negative benefits on the environment of using organic molecules and reactions for solving problems.

MODULE 7: ORGANIC REACTIONS

Section 1: General Reactions

- Substitution
- Addition
- Elimination
- Hydrocarbon Combustion
- Saponification
- Cracking
- Reforming
- Esterification

Section 2: Polymers and Applications

- Polymerization
- Living versus Nonliving Systems
- Careers Involving Organic Chemistry
- Applications of Organic Chemistry
- Positive and Negative Consequences

Evaluation

The evaluation of this module will be based on two assignments:

Section 1 Assignment	**45 marks**
Section 2 Assignment	**55 marks**
TOTAL	**100 marks**

Materials and Equipment

The following is a list of materials necessary for completing the investigations and activities in Module 7. Amounts stated represent requirements per student.

Section 1: Activity 3

Investigation 9.4: Synthesizing an Ester

See page 265 of *Nelson Chemistry* for a complete list of materials.

Investigation: Making Soap

- 50 g of clean fat (beef, pork, or lamb; or lard from the supermarket)
- 50 mL of 3.5 mol/L $NaOH_{(aq)}$ (sodium hydroxide)
- glass stirring rod
- (2) milk carton bottoms from 250 mL, 500 mL, or 1 L cartons with 2 cm high walls
- apron
- 250 mL beaker
- 100 mL graduated cylinder
- hot plate
- thermometer
- safety goggles

Additional Resources

_____. 1979. *Alchem Chemistry*. Ethylene and Its Derivatives, Foods and Their Analogs, and Organic Chemistry. Edmonton: J.M. LeBel Enterprises Ltd.

NIMBY. This is an environmental game on landfills available to the teacher from Alberta Environment Education Branch, 12th Floor, 9820-106 Street, Edmonton, Alberta, T5K 2J6 (403-427-6310).

Wibraham, A.C., D.D. Staley, et al. 1993. *Addison-Wesley Chemistry*. 3d ed. Don Mills, Ontario: Addison-Wesley Publishing Company, Inc.

Possible Media

Videos

Organic Chemistry 1 Series. (1987) TV Ontario, Box 200, Station Q, Toronto, Ontario, M4T 2T1 (416-484-2600). (ACCESS Network)
Includes segments on Polyethylene and Harvest of Enzymes.

Organic Chemistry 2 Series. (1988) TV Ontario. (ACCESS Network)
Includes segments on ASA, Soaps, Glues, and Cosmetics.

Petroleum: River of Energy. (1989) (ACCESS Network)

Planet Under Pressure Series. (1991) TV Ontario.
Includes a segment on Ozone.

Laser Videodisc

Cosmic Chemistry. (1992) Optical Data Corporation, New Jersey.

Section 1: General Reactions

Key Concepts

This section looks at simple organic reactions of addition, substitution, elimination, esterification, saponification, combustion, cracking, and reforming. Students should develop a basic understanding of how these reactions proceed and some applications for both the reactions and the organic molecules involved in the reactions. Possible alternative avenues of interest could include trips to facilities that use these reactions. This would include oil refineries, ethylene productions plants, petrochemical facilities, and soap or detergent production facilities.

The use of structural diagrams is stressed and the condensed structural diagram is also mentioned as a short cut.

Teaching Suggestions

- Ensure the student uses the molecular model kit extensively. This will provide the student with a better view of the concepts and reduce many conceptual problems.
- Activity 3 provides for some laboratory experience, if facilities are available. For Investigation 9.4: Synthesizing an Ester, Part A, you may wish to substitute the formation of banana oil (1-methylbutyl ethanoate) for ethyl ethanoate (nail polish remover). To substitute for banana oil, use 2 mL of glacial ethanoic (acetic) acid and 3 mL of n-amyl alcohol (2-hydroxypentane).

Section 1: Assignment Answer Key (45 marks)

1. a. $H-\overset{\overset{H}{|}}{\underset{\underset{H}{|}}{C}}-H + Cl_2 \xrightarrow{\text{light}} H-\overset{\overset{H}{|}}{\underset{\underset{H}{|}}{C}}-Cl + HCl$ **(2 marks)**

b. $CH_3-CH=CH_2 + HBr \longrightarrow CH_3-CH_2-\overset{\overset{Br}{|}}{CH_2}$ **or** $CH_3-\overset{\overset{Br}{|}}{CH}-CH_3$ **(2 marks)**

c. $CH_3-\overset{\overset{Cl}{|}}{CH_2} + OH^- \longrightarrow CH_2=CH_2 + H_2O + Cl^-$ **(2 marks)**

d. $CH \equiv CH + 2\,H_2O \xrightarrow{\text{catalyst}} \underset{\underset{OH}{|}}{CH_2}-\underset{\underset{OH}{|}}{CH_2}$ **or** $CH_3-\underset{\underset{OH}{|}}{\overset{\overset{OH}{|}}{CH}}$ **(2 marks)**

e.

(2 marks)

f. $2\,CH_3-\underset{\underset{CH_3}{|}}{\overset{\overset{CH_3}{|}}{C}}-CH_2-\overset{\overset{CH_3}{|}}{CH}-CH_3 + 25\,O_2 \xrightarrow{\text{spark}} 16\,CO_{2(g)} + 18\,H_2O_{(g)}$ **(2 marks)**

g. $CH_3-\overset{\overset{O}{||}}{C}-OH + CH_3-OH \xrightarrow{H^+} CH_3-\overset{\overset{O}{||}}{C}-O-CH_3 + H_2O$ **(2 marks)**

2. a. **Substitution**

- **Description**

  Substitution involves the replacement of a single hydrogen atom or functional group with another functional group. Light is usually required and two products are formed.

- **Equation**

  $CH_3-CH_3 + Cl_2 \xrightarrow{\text{light}} CH_3-CH_2-Cl + HCl$

  or

  $CH_3-CH_2-Br + HF \longrightarrow CH_3-CH_2-F + HBr$ **(3 marks)**

b. **Addition**

- **Description**

  This reaction involves the addition of two atoms across a multiple bond. One product is formed and no light is required.

- **Equation**

$$CH_2{=}CH_2 + Br_2 \longrightarrow CH_2(Br)-CH_2(Br)$$ (Other examples are possible.) **(3 marks)**

c. **Elimination**

- **Description**

In this reaction two atoms or group of atoms are removed from a molecule. A catalyst is required and two products are formed, along with a multiple bond.

- **Equation**

$$CH_3-CH_3 \xrightarrow{\text{catalyst}} CH_2{=}CH_2 + H_2$$ (Other examples are possible.) **(3 marks)**

3. a. **Combustion**

Hydrocarbon combustion involves the burning of hydrocarbons for producing energy. The process requires oxygen.

$$R-H + O_2 \longrightarrow CO_2 + H_2O + \text{energy}$$

This is the basis for the petroleum industry – to supply energy via combustion. **(2 marks)**

b. **Cracking**

Cracking is the breaking of large alkanes into smaller alkanes, without oxygen present. It requires a catalyst and heat. This allows for an increased production of needed fuels. **(2 marks)**

c. **Reforming**

Reforming involves the combining of smaller hydrocarbons into larger hydrocarbons, without oxygen present and with a catalyst. This allows for increased production of higher grade (better) fuels and synthetic lubricants. **(2 marks)**

4. The reaction sequence for producing ethyl methanoate may be outlined as follows:

Equation Number	Equation	Reaction Type
1	$CH_3-CH_3 \xrightarrow{\text{catalyst}} CH_2{=}CH_2 + H_{2(g)}$ ethane ethene hydrogen	This is an elimination reaction, dehydrogenation. This reaction creates a double bond to allow the formation of ethanol.
2	$CH_2{=}CH_2 + H_2O \longrightarrow CH_3-CH_2-OH$ ethene water ethanol	This is an addition reaction. This reaction creates the alcohol which is required for making ethyl methanoate.
3	$CH_3-CH_2-OH + HO-C(=O)H \xrightarrow{H^+} CH_3-CH_2-O-C(=O)H + H_2O$ ethanol methanoic acid ethyl methanoate water	This is an esterification reaction. This is the final reaction in creating the ester ethyl methanoate.

(9 marks)

5. **Equation**

$$CH_3-CH_2-O-\overset{\overset{\displaystyle O}{\|}}{C}H + NaOH \longrightarrow CH_3-CH_2-OH + Na^+\ {}^-O-\overset{\overset{\displaystyle O}{\|}}{C}H$$

ethyl methanoate (base) ethanol methanoic acid sodium salt (sodium methanoate)

Products: Types of Compounds

An alcohol and a carboxylic acid are formed.

Industrial Uses

This process is used for producing soaps and detergents. **(4 marks)**

6. Esters create the flavouring and aromas in fruits and flowers. They may be made artificially and are used to flavour food and provide aroma. Esters are used as solvents in cosmetics, in perfumes, and in medicines, and for creating synthetic fibres. **(3 marks)**

Section 2: Polymers and Applications

Key Concepts

This section focuses on the polymerization reaction and the uses of polymers in society. A comparison is drawn between a living and a nonliving system by looking at respiration versus hydrocarbon combustion. Finally, the role of organic chemistry in various careers and the possible positive and negative effects of using organic chemistry for solving problems are explored.

Possible variations to lesson presentation would be to visit a plant that makes plastics; to spend some time with an individual whose career involves organic chemistry such as a pharmacist, chemist, or lab technician; or to visit an area where organic chemistry shows both positive and negative benefits, such as a landfill site or a body of water that has pesticide pollution.

Teaching Suggestions

In Activity 3 try to ensure that the student does the garbage collection and evaluation over a 24-hour period. Stop the lesson for 24 hours until the evaluation has been completed – the activity could provide some fun and a useful break.

Section 2: Assignment Answer Key (55 marks)

1. a. • **Addition** polymerization:

$$\boxed{\begin{array}{c} Cl \\ | \\ CH=CH_2 \end{array}} \longrightarrow \left(\begin{array}{c} Cl \\ | \\ -CH-CH_2- \end{array} \right)_n$$

• **Condensation** polymerization:

$$\boxed{HO-\overset{\overset{\displaystyle O}{\|}}{C}-\overset{\overset{\displaystyle O}{\|}}{C}-OH} + \boxed{H_2N-CH_2-NH_2} \longrightarrow \left(-\overset{\overset{\displaystyle O}{\|}}{C}-\overset{\overset{\displaystyle O}{\|}}{C}-\underset{\underset{\displaystyle H}{|}}{N}-CH_2-\underset{\underset{\displaystyle H}{|}}{N}- \right)_n + n\,H_2O$$

(4 marks)

b. The difference between the two types of polymerization reactions is that one type forms only the **polymer** and the other type forms the **polymer** and **water**. **(2 marks)**

2. **Propene Monomer**

$$CH_3-CH=CH_2 + CH_3-CH=CH_2 \longrightarrow \bullet\overset{\overset{CH_3}{|}}{CH}-CH_2\bullet + \bullet\overset{\overset{CH_3}{|}}{CH}-CH_2\bullet$$

Polymer

$$\bullet\overset{\overset{CH_3}{|}}{CH}-CH_2\bullet + \bullet\overset{\overset{CH_3}{|}}{C}-CH_2\bullet \longrightarrow \left(-\overset{\overset{CH_3}{|}}{CH}-CH_2-\overset{\overset{CH_3}{|}}{CH}-CH_2-\right)_n$$

Bonding electrons are opened up from the double bonds in the first reaction. Bonds are made between the monomers to form the polymer chain in the second reaction. **(4 marks)**

3. a. True **(1 mark)**

   b. True **(1 mark)**

   c. False **(1 mark)**

   A polyester is formed from bifunctional monomers with hydroxyl and carboxyl groups. **(1 mark)**

   d. False **(1 mark)**

   A polyamide is formed from bifunctional monomers with carboxyl and amine groups. **(1 mark)**

4. Answers will vary. Any three plastic products such as plastic bags, PVC pipe, or foam insulation are acceptable. **(3 marks)**

5. Polymer products have different physical and chemical properties because of different **functional groups** attached to the monomers, varied numbers of **monomers** in the polymer chain, and different amounts of **branching** in the polymer. **(3 marks)**

6. Examples of natural polymers could include proteins, carbohydrates, DNA, and natural rubber.

Polymer	Function
Proteins	• form the structure of enzymes • are crucial in the formation of tissue
Carbohydrates	• provide fuel for the body
DNA	• provides the genetic requirements of the body
Natural rubber	• used for seals, car tires, and rubber balls

(3 marks)

7. An example of a nonliving system could be a car engine; a living system could be a human body. The human body is more efficient than the car engine because there is less waste of energy due to heat loss. **(3 marks)**

8. Examples of career choices involving organic chemistry could include the following: petroleum engineer, cosmetics chemist, or pharmacist.

Career Choice	Types of Organic Compounds
Petroleum engineer	This career involves working primarily with aliphatic hydrocarbons (alkanes, alkenes, alkynes).
Cosmetic chemist	This career involves working mainly with aromatics and hydrocarbon derivatives (alkehydes, ketones, esters).
Pharmacist	This career involves working primarily with complex organic compounds produced in the drug industry.

(4 marks)

9. Answers may vary. An example is given here.

Organic Compound Class – Chlorofluorocarbons	
Positive Effects	**Negative Effects**
The production of chlorofluorocarbons (CFCs) allowed for refrigeration. This decreased food spoilage and allowed for frozen food storage and air-conditioned comfort.	CFCs destroy ozone in the atmosphere. The loss of ozone allows for increased UV radiation levels to reach the Earth's surface. UV radiation can impair vision, cause skin cancer, decrease immunity, decrease food production, and interfere with the food chain.

(5 marks)

10. a.

Hydrogen as a Power Source	
Benefits	**Risks**
• clean burning • reduces use of fossil fuels • possible reduction in global warming • unlimited supply • renewable resource	• expensive to make (uses much electricity) • very explosive (special precautions needed)

(6 marks)

b. Based on the evidence gathered, considering the significant number of benefits compared to risks, hydrogen would be a beneficial fuel. **(2 marks)**

c. The assessment of this question depends on the completeness of the assessment spreadsheet. It should not matter what the individual level values are on the spreadsheet, as long as it has been completed. The marks for this question could be given based on percentage of spreadsheet completion. For example, if 80% of the level values were filled in, the student could receive 8 out of 10. (See the shaded areas in the following chart Charting Growth in Science Skills.) **(10 marks)**

CHARTING GROWTH IN SCIENCE SKILLS

Feedback From Assignments			Initiating and Planning		Collecting and Recording		Organizing and Communicating		Analysing		Synthesizing and Integrating		Evaluating	
Module	Section	Question	Self	Teacher	Self	Teacher	Self	Teacher	Self	Teacher	Self	Teacher	Self	Teacher
1	1	4												
	1	6												
	2	6												
	3	7												
2	1	11												
	2	17												
	2	18												
3	1	8												
	2	7												
4	1	1												
	1	2												
	2	3												
	3	1												
5	1	1												
	2	5												
6	1	2												
7	2	10												

Note: The shaded areas indicated for Module 7 may only be shown in the student's assessment box.

Final Test

Note:

Calculators are recommended when writing this test. A periodic table and other necessary information are included with this test.

Included here is the answer key to the final test and the student's copy of the final test which is designed for photocopying and possible faxing.

Note:

The answer key and student's copy of this final test should be kept secure by the teacher. Students should not have access to this test until it is assigned in a supervised situation. The answers should be stored securely and retained by the teacher at all times.

CHEMISTRY 20

FINAL TEST ANSWER KEY

Part A: Multiple Choice (48 marks)

1.	D	9.	B	17.	D	25.	B	33.	B	41.	A
2.	A	10.	A	18.	C	26.	D	34.	D	42.	D
3.	D	11.	C	19.	B	27.	A	35.	B	43.	B
4.	C	12.	B	20.	D	28.	C	36.	B	44.	C
5.	B	13.	A	21.	D	29.	C	37.	D	45.	A
6.	A	14.	C	22.	B	30.	B	38.	B	46.	D
7.	D	15.	C	23.	C	31.	C	39.	D	47.	D
8.	B	16.	D	24.	C	32.	D	40.	B	48.	A

Part B: Short Answer (32 marks)

1. Biomagnification is the build-up of toxic substances in successive organisms in a food chain. Several examples are possibilities; mercury or PCBs are two. The answers must refer to these materials increasing in concentration in each member of a food chain example used. **(4 marks)**

2. Solution A is $NaCl_{(aq)}$ because the indicator data shows that the pH of solution A is around 7, which is neutral. $NaCl_{(aq)}$ is a neutral substance. Solution B is $NaOH_{(aq)}$ because the indicator data shows that the pH of solution B is above 8, which is basic. $NaOH_{(aq)}$ is a basic substance. Solution C is $HCl_{(aq)}$ because the indicator data shows that the pH of solution C is below 6, which is acidic. $HCl_{(aq)}$ is an acidic substance. **(3 marks)**

3. a. As the temperature rises, the gas molecules in the tire move more quickly and collide with the tire wall with greater force and greater frequency, thereby increasing the pressure in the tire.

   b. As the balloon rises, the atmospheric pressure decreases. The pressure outside the balloon is therefore less than that inside, so the greater inner pressure forces the soft skin of the balloon to expand until the pressure is equal.

   c. The diaphragm contracts, causing the thoracic cavity to expand. This reduces the pressure on the lungs, which also expand. The pressure inside the lungs is less than the atmospheric pressure, and air flows into the lungs. **(4 marks** – Any **two** points are to be explained.)

4. $Mg_{(s)} + 2\ HCl_{(aq)} \rightarrow MgCl_{2(aq)} + H_{2(g)}$

   0.110 g

   $$n_{(H_2)} = 0.110\ \cancel{g\ Mg} \times \frac{1\ \cancel{mol\ Mg}}{24.31\ \cancel{g\ Mg}} \times \frac{1\ mol\ H_2}{1\ \cancel{mol\ Mg}}$$

   $$= 0.00452\ mol\ H_2$$

   $104.2\ mL\ H_2 = 0.1042\ L\ H_2$

   $$pv = nRT \text{ or } R = \frac{pv}{nT}$$

   $$R = \frac{100.14\ kPa\ (0.1042\ L)}{(0.00452\ mol)(291\ K)}$$

   $$R = 7.93\ \frac{kPa \bullet L}{mol \bullet K}$$ (7.92 is also acceptable) **(4 marks)**

5. Final buret reading = 49 mL (49.0)
Initial buret reading = 23 mL (23.0)

Net volume $\left(NaOH_{(aq)}\right)$ = 26 mL (26.0)
= 0.026 L

$HCl_{(aq)} + NaOH_{(aq)} \rightarrow H_2O_{(l)} + NaCl_{(aq)}$

10.0 mL 0.150 mol/L

$$[HCl] = 0.026\ \cancel{L\ NaOH} \times \frac{0.150\ \cancel{mol\ NaOH}}{\cancel{L\ NaOH}} \times \frac{1\ mol\ \cancel{HCl}}{1\ \cancel{mol\ NaOH}} \times \frac{1}{0.0100\ L\ \cancel{HCl}}$$

= 0.39 mol/L (0.390)

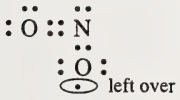
The concentration of the $HCl_{(aq)}$ is 0.39 mol/L. **(4 marks)**

6. a. The following procedure could be used for finding the activity series of the metals:

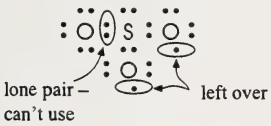
- Clean each metal sample with steel wool.
- Place 5 mL (or less) of 1.0 mol/L $HCl_{(aq)}$ (or dilute $HCl_{(aq)}$) in each of 4 test tubes (or spots on a spot plate).
- Record observations carefully.
- Safely dispose of the used materials. **(2 marks)**

b. The degree of bubbling of each sample will give an idea of the relative reactivity of each metal. **(1 mark)**

7. Nitrogen dioxide and sulphur trioxide do not follow the octet rule, which is the main bonding concept of this course.



The double bond switches back and forth between oxygens (resonates).



This dot diagram shows that the octet rule cannot be followed.

These compounds must therefore follow other bonding principles. **(2 marks)**

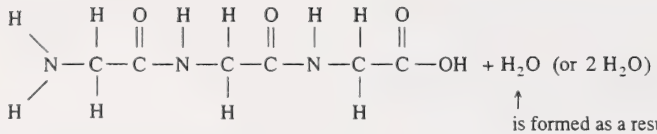
8. a. 2-ethyl-3-methyl-1-butene **(1 mark)**

b. 3-methyl-2-phenylpentane **(1 mark)**

9. The two possible isomers of C_2H_6O are as follows:

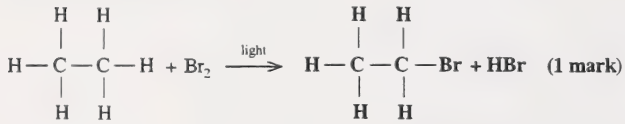
$CH_3 — O — CH_3$ **(1 mark)**

$CH_3 — CH_2 — OH$ **(1 mark)**

10. 

$+ H_2O$ (or $2\ H_2O$)

↑ is formed as a result of the polymerization **(2 marks)**

11. a. 

(1 mark)

b. The reaction type is **substitution**. **(1 mark)**

CHEMISTRY 20

FINAL TEST

GENERAL INSTRUCTIONS

YOU HAVE **TWO** HOURS TO COMPLETE THIS TEST. Work through the entire test answering the questions you are sure you know. You will then be able to concentrate on the questions of which you are not quite sure.

TOTAL MARKS: 80

PART A: Multiple Choice	48 marks
PART B: Short Answer	32 marks

Note: Calculators are recommended when writing this test.
A periodic table and other necessary information are included at the end of this test.

Value

PART A: MULTIPLE CHOICE

48

All multiple-choice questions must be answered on the Part A Response Page included in your test.

Read each question carefully and decide which of the choices BEST completes the statement or answers the question. Locate the question number on the Response Page and place your answer in the corresponding blank.

1. A student doing an experiment in the lab accidentally added excess water to his aqueous test solution. The result of this was

   A. the mass of solute decreased
   B. the mass of solvent remained the same
   C. the number of moles of solute increased
   D. the concentration of the solution decreased

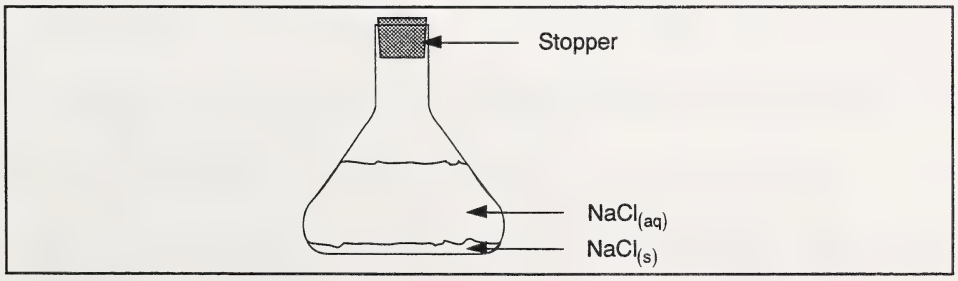
2. A light bulb apparatus used for indicating electrical conductivity of solutions is placed in the four unlabelled solutions listed here. The only solution that will cause the bulb to light up is

   A. $NH_4Cl_{(aq)}$
   B. $H_2O_{2(aq)}$
   C. $CH_3OH_{(aq)}$
   D. $C_{12}H_{22}O_{11(aq)}$

3. Which of the following substances would form a precipitate when reacted with a sodium sulphate solution but not when reacted with a potassium hydroxide solution?

   A. silver chlorate
   B. lead(II) acetate
   C. sodium phosphate
   D. barium nitrate

4. **Use the following information to answer this question.**



Identify the correct statement about this saturated solution.

   A. The solution will become less concentrated as solid continues to settle out.
   B. The solution will become more concentrated as time passes.
   C. The rate of dissolving equals the rate of crystallizing.
   D. The solution shows evidence of chemical change.

5. X-rays of patients' intestines can be taken with the help of barium sulphate. Barium is a heavy metal and absorbs X-rays. In solution, barium ions are very poisonous. The reason humans can ingest barium sulphate is

   A. barium ions are neutralized by the hydrochloric acid in the stomach
   B. barium sulphate has a very low solubility
   C. barium is covalently bonded to the sulphur atom in barium sulphate
   D. X-rays neutralize barium ions

6. **Use the following information to answer this question.**

I	Dissolve the solute in about 50 mL of water.
II	Dissolve the solute in 100.0 mL of water.
III	Dilute the solution to 100.0 mL.
IV	Transfer the solute to a volumetric flask.
V	Transfer the solution to a volumetric flask.
VI	Mix thoroughly.

   A student obtains, in a beaker, the correct mass of solute needed to make 100.0 mL of solution. The best steps, in the correct order, to complete the preparation of the solution are

   A. I, V, III, VI
   B. I, VI, IV, III
   C. II, V, III, VI
   D. IV, III, VI

7. Concentrated hydrochloric acid has a concentration of 12.4 mol/L. If a person requires 25.0 L of 4.20 mol/L acid to etch a cement floor, the volume of the concentrated acid that would be required for dilution is

   A. 105 L
   B. 73.8 L
   C. 2.08 L
   D. 8.47 L

8. The equation which CORRECTLY represents the dissociation of iron(III) chloride in water is

   A. $2\ FeCl_{3(s)} \rightarrow 2\ Fe^{3+}{}_{(aq)} + 3\ Cl_2{}^{-}{}_{(aq)}$
   B. $FeCl_{3(s)} \rightarrow Fe^{3+}{}_{(aq)} + 3\ Cl^{-}{}_{(aq)}$
   C. $Fe_3Cl_{(s)} \rightarrow 3\ Fe^{3+}{}_{(aq)} + Cl^{-}{}_{(aq)}$
   D. $FeCl_{3(s)} \rightarrow Fe_{(s)} + 3\ Cl_{(aq)}$

9. The best substance to sprinkle on a puddle of spilled battery acid to help neutralize it would be

   A. table salt
   B. baking soda
   C. bleach
   D. vinegar

10. **Use the following information to answer this question.**

A student performed a number of tests on four solutions.

Solution	Colour of Red Litmus	Colour of Blue Litmus	Conductivity
I	red	blue	yes
II	red	red	yes
III	red	blue	no
IV	blue	blue	yes

The solutions listed in the following order – acidic, basic, neutral ionic, and neutral molecular – would be

   A. II, IV, I, III
   B. III, II, I, IV
   C. II, IV, III, I
   D. IV, II, III, I

11. According to Arrhenius' theory,

   A. acids turn litmus red
   B. bases are electrolytes
   C. acids release $H^+_{(aq)}$
   D. bases are slippery

12. The correct statement of Charles' Law is

   A. all gas samples of the same volume and pressure contain the same number of molecules
   B. the volume of a gas sample varies with the temperature
   C. the volume of a gas sample varies with the pressure
   D. the volume of a gas sample varies with the amount of gas

13. Under the same conditions of temperature and pressure, equal volumes of nitrogen gas and helium gas contain equivalent

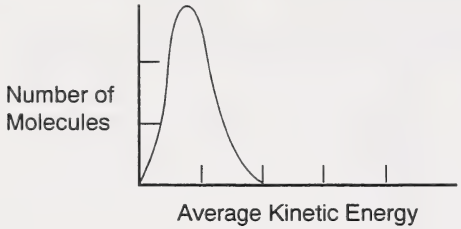
   A. moles
   B. bonding forces
   C. atoms
   D. masses

14. Butane is a fuel used in lighters, hair curlers, and soldering torches. If a butane lighter contains 2.00 g of butane, the volume this amount of butane would occupy at STP is

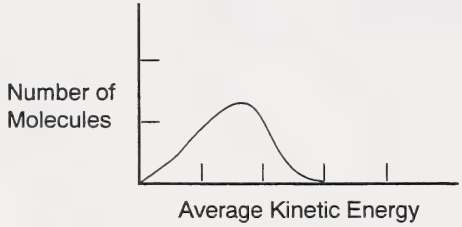
A. 0.0714 L
B. 0.106 L
C. 0.770 L
D. 0.852 L

15. The graph that represents a gas with the highest temperature is (assume the scales of all the graphs are the same)

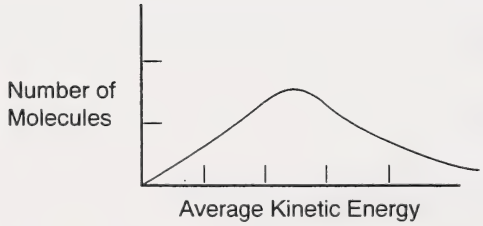
A.



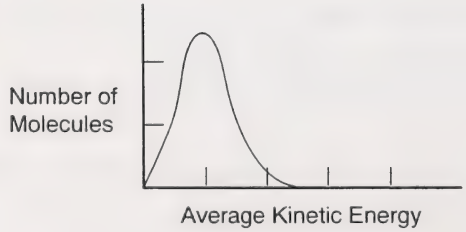
B.



C.



D.



16. Choose the statement that is a correct representation of the identified scientist's ideas.

    A. Charles recognized that volume is directly proportional to Celsius temperature – $v \propto T$.
    B. Avogadro's hypothesis states that equal volumes of gases at any temperature and pressure contain equal numbers of molecules – $v \propto n$.
    C. When Charles' Law, Boyle's Law, and Avogadro's hypothesis are combined, the mathematical expression for their ideas is $v = nT / p$.
    D. Boyle suggested that volume is inversely proportional to pressure – $v \propto 1/p$.

17. **Use the following information to answer this question.**

$$N_{2(g)} + 3\,H_{2(g)} \rightarrow 2\,NH_{3(g)}$$

The chemical principle that makes it possible to interpret the given equation as **1 volume** of nitrogen gas will react with **3 volumes** of hydrogen gas is

    A. Boyle's Law
    B. Charles' Law
    C. the law of multiple proportions
    D. Avogadro's hypothesis

18. What new volume would a gas occupy at SATP if its original volume was 2.65 L at 65.8 kPa and 25.0°C?

    A. 4.03 L
    B. 1.90 L
    C. 1.74 L
    D. 1.60 L

19. When a bottle of carbonated soft drink is left open overnight, the drink loses its carbonation. Identify the correct explanation for this reaction.

    A. Only the liquid part of the soft drink evaporates into the atmosphere, giving the soft drink a decarbonated taste.
    B. The pressure inside the bottle that holds the gas in the soft drink is released, allowing the gas to escape.
    C. The flavouring of the soft drink oxidizes with the now available oxygen, allowing the gas to be released.
    D. This is not true because all you have to do is place the lid back on, shake the bottle, and the carbonation returns.

20. In a reaction, 8.00 g of $O_{2(g)}$ were consumed and 7.34 g of $CO_{2(g)}$ produced. No unreacted fuel remained. A possible equation that could represent this reaction is

    A. $CH_{4(g)} + 2\,O_{2(g)} \rightarrow CO_{2(g)} + 2\,H_2O_{(g)}$
    B. $C_3H_{8(g)} + 5\,O_{2(g)} \rightarrow 3\,CO_{2(g)} + 4\,H_2O_{(g)}$
    C. $C_3H_{4(g)} + 4\,O_{2(g)} \rightarrow CO_{2(g)} + 2\,H_2O_{(g)}$
    D. $C_2H_{4(g)} + 3\,O_{2(g)} \rightarrow 2\,CO_{2(g)} + 2\,H_2O_{(g)}$

21. **Use the following information to answer this question.**

$$C_3H_{8(g)} + 5\ O_{2(g)} \rightarrow 3\ CO_{2(g)} + 4\ H_2O_{(g)}$$

In a propane barbecue 11.0 g of $C_3H_{8(g)}$ are burned. To calculate the mass of $CO_{2(g)}$ produced, a student should use the following unit analysis procedure

A. $11\ g\ C_3H_8 \times \frac{44.11\ g\ C_3H_8}{1\ mol\ C_3H_8} \times \frac{3\ mol\ CO_2}{1\ mol\ C_3H_8} \times \frac{44.01\ g\ CO_2}{1\ mol\ CO_2}$

B. $11.0\ g\ C_3H_8 \times \frac{1\ mol\ C_3H_8}{44.11\ g\ C_3H_8} \times \frac{3\ mol\ CO_2}{1\ mol\ C_3H_8} \times \frac{132.03\ g\ CO_2}{1\ mol\ CO_2}$

C. $11.0\ g\ C_3H_8 \times \frac{1\ mol\ C_3H_8}{44.11\ g\ C_3H_8} \times \frac{1\ mol\ CO_2}{3\ mol\ CO_2} \times \frac{44.01\ g\ CO_2}{1\ mol\ CO_2}$

D. $11.0\ g\ C_3H_8 \times \frac{1\ mol\ C_3H_8}{44.11\ g\ C_3H_8} \times \frac{3\ mol\ CO_2}{1\ mol\ C_3H_8} \times \frac{44.01\ g\ CO_2}{1\ mol\ CO_2}$

22. When separating a solid from a solution by the process of filtration, the substance that comes through the filter paper is known as the

A. precipitate
B. filtrate
C. solvent
D. solute

23. The technological procedure known as "titration" produces very precise volume measurements that are used by analysts. Identify the procedural situation that would produce poor results.

A. The level of the solution in the buret is below the 0.00 mL position before the titration is started.
B. Several drops of indicator are added to the Erlenmeyer flask before the titration is started.
C. The tip of the buret is not completely filled with solution before the titration is started.
D. The solution in the Erlenmeyer flask is constantly swirled to mix the contents during the titration.

24. **Use the following information to answer this question.**

> Chlorine used for bleaching many products including wood pulp can be manufactured from salt water using the "chlor-alkali" process. The dissociation equation for sodium chloride is
>
> $$NaCl_{(s)} \rightarrow Na^{+}_{(aq)} + Cl^{-}_{(aq)}$$
>
> The chloride ions are then converted to chlorine gas using electricity, according to this equation
>
> $$2\ Cl^{-}_{(aq)} \rightarrow Cl_{2(g)} + 2\ e^{-}$$

To manufacture 10 mol of chlorine gas requires _____ mol of chloride ions or _____ mol of sodium chloride. (Keep the same order.)

A. 10, 10
B. 20, 10
C. 20, 20
D. 10, 20

25. **Use the following information to answer this question.**

> Sulphur dioxide escaping from a natural gas well may react with water to produce an acid that damages the environment according to this equation.
>
> $$SO_{2(g)} + H_2O_{(l)} \rightarrow H_2SO_{3(aq)}$$

The predicted mass of sulphur dioxide that would produce 0.50 mol of $H_2SO_{3(aq)}$ is

A. 0.50 g
B. 32 g
C. 41 g
D. 64 g

26. **Use the following information to answer this question.**

> Hard water contains many dissolved metals which may react with soap to form a precipitate or "soap scum." A student designs an experiment to determine which brand of soap produces the least amount of "soap scum."

The easiest method by which the student could find the mass of the precipitate is

A. crystallization
B. titration
C. distillation
D. filtration

27. **Use the following information to answer this question.**

> A student wished to check his theoretical value of an experiment for accuracy. He carried out an experiment by placing a premassed piece of zinc in a beaker containing 1.0 mol/L hydrochloric acid. He then measured the mass of the leftover zinc after the reaction was completed. The following data were collected:
>
> theoretical value for the mass of zinc reacted = 2.2 g
> mass of zinc before reaction = 4.8 g
> mass of zinc after complete reaction = 2.7 g

The percent error (percent difference) for the amount of zinc reacted is

A. 4.5%
B. 4.8%
C. 19%
D. 23%

28. **Use the following information to answer this question.**

> A student carries out an experiment to confirm her prediction of the mass of precipitate that should form in a reaction. Her laboratory notes provide the following information:
>
> predicted mass (by stoichiometry) = 1.64 g
> mass of filter paper = 2.11 g
> mass of filter paper and precipitate = 6.19 g

Identify the most likely explanation for these results.

A. The student did not rinse the precipitate with distilled water a second time.
B. Some precipitate has leaked through the filter paper.
C. The precipitate has not dried sufficiently.
D. The student rinsed too much and dissolved some of the precipitate.

29. **Use the following information to answer this question.**

> Hydrochloric acid is used to clean rust from iron. The equation for this reaction can be written as
>
> $$3\ HCl_{(aq)} + \underset{\text{rust}}{Fe(OH)_{3(s)}} \rightarrow FeCl_{3(aq)} + 3\ HOH_{(l)}$$

The mass of rust that can be removed with 25 mL of 0.50 mol/L hydrochloric acid is

A. 72 g
B. 4.0 g
C. 0.45 g
D. 0.30 g

30. **Use the following information to answer this question.**

$$H_{2(g)} + 1/2\ O_{2(g)} \rightarrow H_2O_{(l)}$$

If 6 mol of oxygen were reacted with 10 mol of hydrogen, the amount of water produced would be

A. 6 mol because oxygen is the limiting species
B. 10 mol because hydrogen is the limiting species
C. 16 mol because the amount of matter is conserved
D. 12 mol because oxygen is the limiting species

31. The reason **ALL** chemical bonds form is to

A. fill the inner orbitals of atoms with electrons, allowing greater stability
B. cause a transfer of the electrons that are not required by one or more elements
C. produce a more stable electron distribution for each atom or ion involved
D. make available more bonding electrons for "attachment" of additional elements

32. **Use the following information to answer this question.**

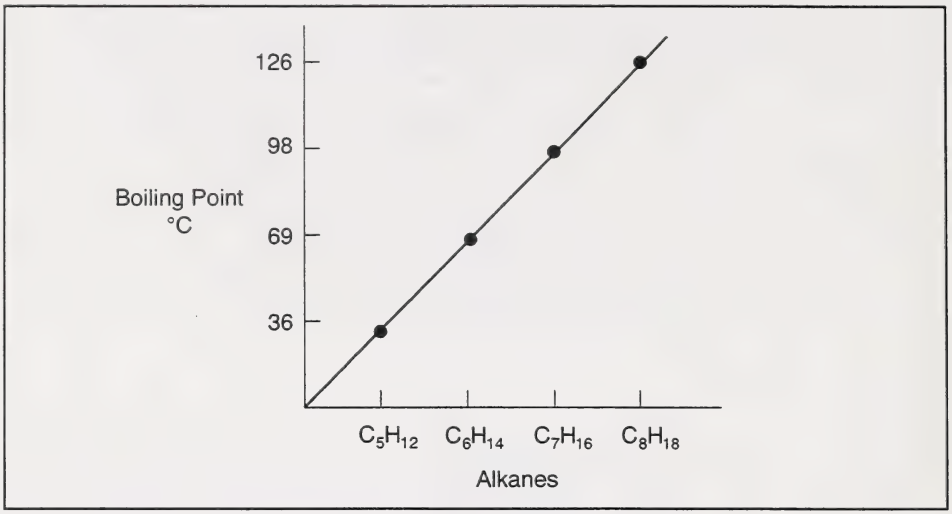
Identify the true statements.

I Ionic bonds involve the sharing of electrons.
II Ionic bonds involve the transfer of electrons.
III Covalent bonds involve the sharing of electrons.
IV Covalent bonds involve the transfer of electrons.
V All bonds have characteristics of both ionic and covalent bonds.

The true statements are

A. I, IV
B. I, IV, V
C. II, III, V
D. II, III

33. **Use the following information to answer this question.**



Identify the statement that explains the graph.

A. Intramolecular forces decrease with an increase in the number of atoms.
B. Intermolecular forces increase with an increase in the number of atoms.
C. Intramolecular forces increase with an increase in the number of atoms.
D. Intermolecular forces decrease with an increase in the number of atoms.

34. **Use the following information to answer this question.**

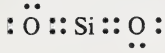
$$CH_{4(g)} + 2\ O_{2(g)} \rightarrow CO_{2(g)} + 2\ H_2O_{(g)} + \text{energy}$$

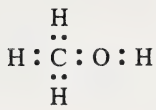
In this chemical reaction

A. the energy released when new bonds are formed is less than the energy absorbed to break the bonds in the reactants
B. the energy absorbed when new bonds are formed is greater than the energy released when reactant bonds are broken
C. the energy absorbed when new bonds are formed is less than the energy released when reactant bonds are broken
D. the energy released when new bonds are formed is greater than the energy absorbed to break the bonds in the reactants

35. The correct electron dot diagram is

A.

B. 

C. 

D.

36. **Use the following information to answer this question.**

> Zinc reacts with oxygen from the air to form the oxide coating on galvanized objects.
>
> $$2\,Zn_{(s)} + O_{2(g)} \rightarrow 2\,ZnO_{(s)}$$

The balanced oxidation half-reaction from the given overall reaction is

A. $O_2 \rightarrow 2\,O + 4\,e^-$
B. $Zn \rightarrow Zn^{2+} + 2\,e^-$
C. $Zn + 2\,e^- \rightarrow Zn^{2+}$
D. $O_2 + 4\,e^- \rightarrow 2\,O_2 + 2\,e^-$

37. NASA scientists found that the extremely high heating of the space shuttle upon reentry was a major problem in the "weakening" of the metal. This was solved by covering the shuttle surface with highly heat-resistant ceramic tiles. Choose the best explanation for the high temperature resistance of the ceramic tiles.

A. The molecules in the ceramic tile must be large and therefore have strong London dispersion forces resulting in a high melting point.
B. The ceramic tiles are probably treated with a nonreactive noble gas, thus are not chemically altered by the high temperature.
C. The tile used must have a metal ionically bonded to a nonmetal in order to achieve the highest possible melting point.
D. The molecules in ceramic tile are held together by network covalent bonds and therefore have a high melting point.

38. **Use the following information to answer this question.**

1. $CH_3OH_{(l)}$ – methanol	4. $MgCO_{3(s)}$ – magnesium carbonate
2. $CaC_{2(s)}$ – calcium carbide	5. $HCN_{(g)}$ – hydrogen cyanide
3. $HCOOH_{(aq)}$ – methanoic acid	

The organic compounds in the list are

A. 2 and 5
B. 1 and 3
C. 1 and 4
D. 2 and 3

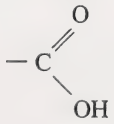
39. **Use the following information to answer this question.**

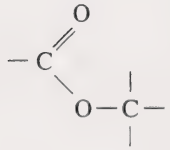
A bromine diagnostic test is used to classify a colourless liquid as saturated or unsaturated. The test involves adding bromine water $\left(Br_{2(aq)}\right)$ to the liquid, mixing and observing the final colour of the solution.

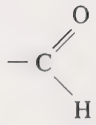
The evidence statement that would positively identify an unsaturated liquid compound is

A. the mixture when shaken becomes yellow and solidifies
B. the orange-brown bromine water does not change in colour
C. the colourless bromine water becomes orange-brown
D. the orange-brown bromine water becomes colourless

40. The clothing industry uses the synthetic fibre known as polyester. The functional group present in all esters is

A. 

B. 

C. 

D. —OH

41. A molecular model kit contains ten black carbon balls and twenty yellow hydrogen balls. The pair of models that could be made **at the same time** with this kit is

A. pentane and propane
B. pentane and benzene
C. butane and hexane
D. propane and hexane

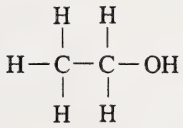
42. **Use the following information to answer this question.**

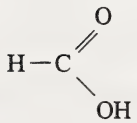
1.	C_2H_4	A.	used as gas line antifreeze
2.	CH_4	B.	the major constituent of natural gas
3.	CH_3OH	C.	vinegar when in a diluted form
4.	CH_3COOH	D.	used in the manufacture of polyethylene plastic

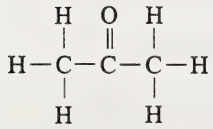
The organic compounds correctly matched with their everyday use are

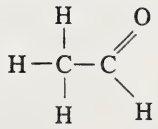
A. 1C, 2A, 3D, 4B
B. 1B, 2D, 3C, 4A
C. 1A, 2C, 3B, 4D
D. 1D, 2B, 3A, 4C

43. An organic compound isolated from a hornet's stinger turned blue litmus to red. This compound could be

A. 

B. 

C. 

D. 

44. Ethane and chlorine react when exposed to ultraviolet light. This reaction will produce

A. 1,2-dichloroethane
B. chloroethane
C. chloroethane and hydrogen chloride
D. chloroethene and hydrogen chloride

45. The correct order of the alkanes, alkenes, and alkynes from most reactive to least reactive is

A. alkynes, alkenes, alkanes
B. alkenes, alkynes, alkanes
C. alkanes, alkynes, alkenes
D. alkynes, alkanes, alkenes

46. **Use the following information to answer this question.**

I. Propene reacts with water.
II. The product of the first reaction is combined with acetic acid and heated for several minutes.

The type of reactions that occur in the first and second reactions, respectively, are

A. substitution and esterification
B. alcoholization and elimination
C. neutralization and addition
D. addition and esterification

47. **Use the following information to answer this question.**

Ethanol can be made in two ways.

- React ethene with gaseous water (steam) in the presence of a catalyst.
- Have yeast decompose sugar.

Comparison of samples of ethanol from the two methods shows

A. the ethanol made from ethene is a secondary alcohol
B. the two samples are isomers
C. only the ethanol made from sugar is found to be nonpoisonous
D. both samples are found to be the same

48. The products of addition polymerization are

A. a polymer only
B. a polymer and water
C. a polymer and hydrogen halide
D. a polymer and carbon dioxide

PART A: RESPONSE PAGE

_____	1.	_____	13.	_____	25.	_____	37.
_____	2.	_____	14.	_____	26.	_____	38.
_____	3.	_____	15.	_____	27.	_____	39.
_____	4.	_____	16.	_____	28.	_____	40.
_____	5.	_____	17.	_____	29.	_____	41.
_____	6.	_____	18.	_____	30.	_____	42.
_____	7.	_____	19.	_____	31.	_____	43.
_____	8.	_____	20.	_____	32.	_____	44.
_____	9.	_____	21.	_____	33.	_____	45.
_____	10.	_____	22.	_____	34.	_____	46.
_____	11.	_____	23.	_____	35.	_____	47.
_____	12.	_____	24.	_____	36.	_____	48.

Name of Student _____ Student I.D. # _____

Name of School _____ Date _____

Value

PART B: SHORT ANSWER

32 Answer each of the following questions using the space provided.

Read each question carefully and communicate your answers in clear, complete sentences unless the response format dictates otherwise. Marks will be awarded for pertinent explanations and answers.

(4 marks) 1. One of the dangers of disposing of chemicals in landfill sites or down the drain is that these substances may undergo biomagnification. Define the term *biomagnification* and give an example of how a specific substance illustrates this concept.

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Name of Student _____ Student I.D. # _____

Name of School _____ Date _____

(3 marks) 2. **Use the following information to answer this question.**

A chemistry student forgot to label three solutions that were made for an experiment. To identify each solution, the student tested each with a set of three indicators. The original solutions made were 0.10 mol/L concentrations of $HCl_{(aq)}$, $NaCl_{(aq)}$, and $NaOH_{(aq)}$. The following data were obtained.

DATA

Property / Solution	Colour of Methyl Orange	Colour of Bromothymol Blue	Colour of Phenophthalein
A	yellow	green	colourless
B	yellow	blue	pink
C	red	yellow	colourless

INDICATOR CHART

Indicator	Colour Range on pH Scale
Methyl orange	0 red 3 orange 5 yellow 14
Bromothymol blue	0 yellow 6 green 8 blue 14
Phenolphthalein	0 colourless 8 light pink 10 pink 14

Identify each of the solutions A, B, and C and give a brief reason for each choice.

_____

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Name of Student _____ Student I.D. # _____

Name of School _____ Date _____

(4 marks) 3. Use the kinetic molecular theory and your knowledge of gas behaviour to explain **any two** of the following phenomena.

a. The pressure in an automobile tire increases on a hot day.

b. The volume of a weather balloon increases as it rises above the surface of the Earth.

c. The diaphragm in your thoracic cavity enables you to breathe in (inhale).

_____

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(4 marks) 4. Students performed an investigation to experimentally determine the value of the gas constant *R*. Magnesium metal was completely reacted in a solution of $HCl_{(aq)}$ and the resulting $H_{2(g)}$ was collected and measured. The following data were obtained.

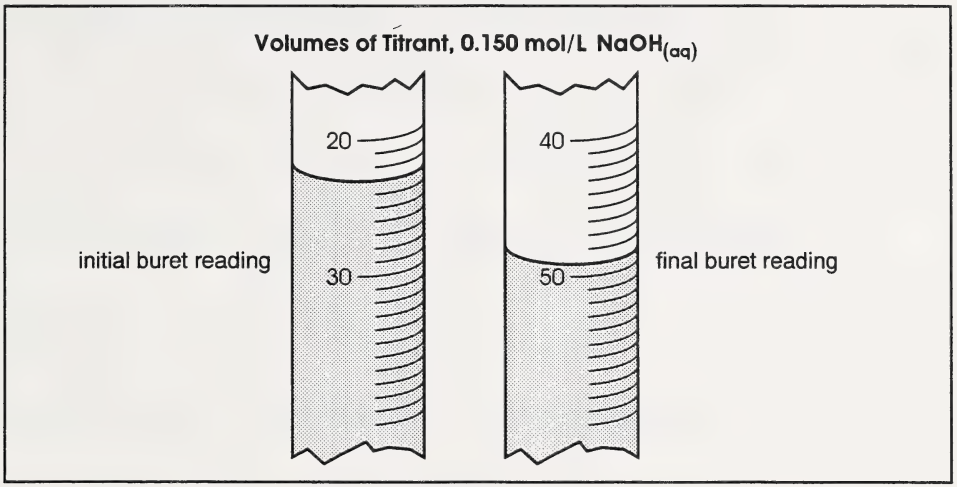
Mass of Mg	0.110 g
Volume of $H_{2(g)}$ collected	104.2 mL
Temperature	18°C
Pressure	100.14 kPa

Based on the experimental data given, calculate the experimental value for the gas constant *R*.

Name of Student _____ Student I.D. # _____

Name of School _____ Date _____

(4 marks) 5. A titration experiment was performed to determine the unknown concentration of an $HCl_{(aq)}$ solution.



The titrant, 0.150 mol/L $NaOH_{(aq)}$, was added until the 10.0 mL of $HCl_{(aq)}$ solution was completely neutralized.

Determine the concentration of the $HCl_{(aq)}$.

Name of Student _____	Student I.D. # _____
Name of School _____	Date _____

(3 marks) 6. A student wished to determine an activity series for the following metals in dilute $HCl_{(aq)}$: calcium, manganese, nickel, and zinc.

a. Briefly describe a procedure the student could use for finding the activity series of these metals.

_____

_____

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b. What observation would the student use to tell which metal is most reactive, etc. to complete the series?

_____

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(2 marks) 7. Briefly describe or show how the bonding in compounds such as nitrogen dioxide and sulphur trioxide illustrate the limitations of the bonding theories in this course. You may wish to use Lewis diagrams for illustrating your point.

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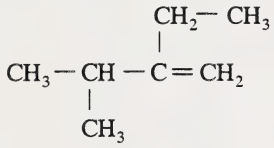
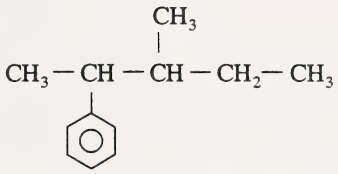
Name of Student _____	Student I.D. # _____
Name of School _____	Date _____

(2 marks) 8. Write the IUPAC name for the following organic compounds.

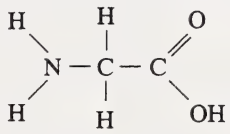
a. 

b. 

_____ _____

(2 marks) 9. Draw the two possible isomers of C_2H_6O, using condensed structural diagrams.

(2 marks) 10. Amino acid monomers can join together in the body by condensation polymerization. The result is a polypeptide polymer.

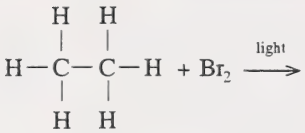


amino acid monomer

Show (by illustration) how three of the given amino acid monomers can be joined by polymerization and indicate any other product(s) of this process.

Name of Student _____	Student I.D. # _____
Name of School _____	Date _____

(2 marks) 11. a. Complete the given reaction.



b. State the reaction type.

_____

Name of Student _____	Student I.D. # _____
Name of School _____	Date _____

Periodic Table of Elements

KEY

1	atomic number
H	symbol of element (italic: synthetically prepared)
1.01	atomic mass (g/mol) ( ) most stable isotope
2.1	electronegativity
−259	melting point (°C) (w-white)
1+	ionic charges: most common
1−	second most common
−253	boiling point (°C)
0.071	density (g/cm^3) (if gas at STP then density is for liquid at boiling point)
2	number of atoms per molecule of most common type
hydrogen	name of element [background shade indicates physical state of element at 101 kPa and 298 K (25°C)]

elements do not form ionic compounds
gas
liquid
solid

GROUP 1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIIIB	9 VIIIB	10 VIIIB	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1 H 1.01 2.1 −259 1+ −253 1− 0.071 2 hydrogen																	2 He 4.00 – −272 −269 0.126 helium
3 Li 6.94 1.0 180 1+ 1347 0.53 lithium	4 Be 9.01 1.5 1278 2+ 2970 1.85 beryllium											5 B 10.81 2.0 2079 2550 2.34 boron	6 C 12.01 2.5 3550 4827 2.26 carbon	7 N 14.01 3.0 −210 3− −196 0.81 2 nitrogen	8 O 16.00 3.5 −218 2− −183 1.14 2 oxygen	9 F 19.00 4.0 −220 1− −188 1.505 2 fluorine	10 Ne 20.18 – −249 −246 1.20 neon
11 Na 22.99 0.9 97.8 1+ 883 0.97 sodium	12 Mg 24.31 1.2 649 2+ 1090 1.74 magnesium											13 Al 26.98 1.5 660 3+ 2467 2.70 aluminum	14 Si 28.09 1.8 1410 2355 2.33 silicon	15 P 30.97 2.1 44.1 w 3− 280 w 1.82 w 4 phosphorus	16 S 32.06 2.5 113 2− 445 2.07 8 sulphur	17 Cl 35.45 3.0 −101 1− −35 1.56 2 chlorine	18 Ar 39.95 – −189 −186 1.40 argon
19 K 39.10 0.8 63.7 1+ 774 0.86 potassium	20 Ca 40.08 1.0 839 2+ 1484 1.55 calcium	21 Sc 44.96 1.3 1541 3+ 2831 3.0 scandium	22 Ti 47.90 1.5 1660 4+ 3287 3+ 4.54 titanium	23 V 50.94 1.6 1890 5+ 3380 4+ 6.1 vanadium	24 Cr 52.00 1.6 1857 3+ 2672 2+ 7.19 chromium	25 Mn 54.94 1.5 1245 2+ 1962 4+ 7.43 manganese	26 Fe 55.85 1.8 1535 3+ 2750 2+ 7.87 iron	27 Co 58.93 1.8 1495 2+ 2870 3+ 8.9 cobalt	28 Ni 58.71 1.8 1453 2+ 2732 3+ 8.9 nickel	29 Cu 63.55 1.9 1083 2+ 2567 1+ 8.96 copper	30 Zn 65.38 1.6 420 2+ 907 7.13 zinc	31 Ga 69.74 1.6 29.8 3+ 2403 5.90 gallium	32 Ge 72.59 1.8 937 4+ 2830 5.32 germanium	33 As 74.92 2.0 – 3− 615 5.73 arsenic	34 Se 78.96 2.4 217 2− 685 4.79 selenium	35 Br 79.90 2.8 −7.2 1− 58 3.12 2 bromine	36 Kr 83.80 – −157 −152 2.41 krypton
37 Rb 85.47 0.8 38.9 1+ 688 1.53 rubidium	38 Sr 87.62 1.0 769 2+ 1384 2.5 strontium	39 Y 88.91 1.3 1522 3338 4.47 yttrium	40 Zr 91.22 1.4 1852 4377 6.51 zirconium	41 Nb 92.91 1.6 2468 4742 8.6 niobium	42 Mo 95.94 1.8 2617 4612 10.2 molybdenum	43 *Tc* 98.91 1.9 2172 4877 11.5 technetium	44 Ru 101.07 2.2 2310 3900 12.4 ruthenium	45 Rh 102.91 2.2 1966 3727 12.4 rhodium	46 Pd 106.40 2.2 1552 2+ 3140 4+ 12.0 palladium	47 Ag 107.87 1.9 962 1+ 2212 10.5 silver	48 Cd 112.41 1.7 321 2+ 765 8.65 cadmium	49 In 114.82 1.7 157 3+ 2080 7.31 indium	50 Sn 118.69 1.8 232 4+ 2270 2+ 7.31 tin	51 Sb 121.75 1.9 631 3+ 1750 5+ 6.70 antimony	52 Te 127.60 2.1 450 2− 990 6.24 tellurium	53 I 126.90 2.5 114 1− 184 4.93 2 iodine	54 Xe 131.30 – −107 −108 3.52 xenon
55 Cs 132.91 0.7 28.4 1+ 678 1.90 cesium	56 Ba 137.33 0.9 725 2+ 1640 3.5 barium	57 La 138.91 1.1 921 3457 6.15 lanthanum	72 Hf 178.49 1.3 2227 4602 13.3 hafnium	73 Ta 180.95 1.5 2996 5425 16.7 tantalum	74 W 183.85 1.7 3410 5660 19.3 tungsten	75 Re 186.21 1.9 3180 5627 21.0 rhenium	76 Os 190.20 2.2 3045 5027 22.6 osmium	77 Ir 192.22 2.2 2410 4130 22.5 iridium	78 Pt 195.09 2.2 1772 4+ 3827 2+ 21.5 platinum	79 Au 196.97 2.4 1064 3+ 2807 1+ 19.3 gold	80 Hg 200.59 1.9 −39.0 2+ 357 1+ 13.6 mercury	81 Tl 204.37 1.8 304 1+ 1457 3+ 11.85 thallium	82 Pb 207.19 1.8 328 2+ 1740 4+ 11.4 lead	83 Bi 208.98 1.9 271 3+ 1560 5+ 9.8 bismuth	84 Po (209) 2.0 254 2+ 962 4+ (9.2) polonium	85 At (210) 2.2 302 1− 373 – 2 astatine	86 Rn (222) – −71 −62 4.4 radon
87 Fr (223) 0.7 (27) 1+ (677) 2.4 francium	88 Ra 226.03 0.9 700 2+ 1140 5.0 radium	89 Ac (227) 1.1 1050 3+ 3200 10.07 actinium	104 Unq (261) unnilquadium	105 Unp (262) unnilpentium	106 Unh (263) unnilhexium	107 Uns (262) unnilseptium		109 Une (266) unnilennium									

58 Ce 140.12 1.1 799 3+ 3426 6.67 cerium	59 Pr 140.91 1.1 931 3+ 3512 6.77 praseodymium	60 Nd 144.24 1.2 1021 3+ 3068 7.00 neodymium	61 *Pm* (145) – 1080 3+ 2460 7.22 promethium	62 Sm 150.35 1.2 1077 3+ 1791 7.52 samarium	63 Eu 151.96 – 822 3+ 1597 2+ 5.24 europium	64 Gd 157.25 1.1 1313 3+ 3266 7.90 gadolinium	65 Tb 158.93 1.2 1356 3+ 3123 8.23 terbium	66 Dy 162.50 – 1412 3+ 2562 8.55 dysprosium	67 Ho 164.93 1.2 1474 3+ 2695 8.80 holmium	68 Er 167.26 1.2 159 3+ 2863 9.07 erbium	69 Tm 168.93 1.2 1545 3+ 1947 9.32 thulium	70 Yb 173.04 1.1 819 3+ 1194 6.97 ytterbium	71 Lu 174.97 1.2 1663 3+ 3395 9.84 lutetium
90 Th 232.04 1.3 1750 4+ 4790 11.7 thorium	91 Pa 231.04 1.5 <1600 5+ – 15.4 protactinium	92 U 238.03 1.7 1132 6+ 3818 4+ 19.1 uranium	93 *Np* 237.05 1.3 640 5+ 3902 19.5 neptunium	94 *Pu* (244) 1.3 641 4+ 3232 6+ – plutonium	95 *Am* (243) 1.3 994 3+ 2607 13.7 americium	96 *Cm* (247) – 1340 3+ – – curium	97 *Bk* (247) – – 3+ – 14 berkelium	98 *Cf* (251) – – 3+ – – californium	99 *Es* (254) – – – – einsteinium	100 *Fm* (257) – – – – fermium	101 *Md* (256) – – – – mendelevium	102 *No* (259) – – – – nobelium	103 *Lr* (257) – – – – lawrencium

Miscellaneous

STP = 0°C and 101.3 kPa
SATP = 25°C and 100 kPa
0°C = 273.15 K

R = 8.31 L•kPa/mol•K
V_{STP} = 22.4 L/mol
V_{SATP} = 24.8 L/mol

TABLE OF COMPLEX IONS

• acetate	CH_3COO^-	• chromate	CrO_4^{2-}	• oxalate	$OOCCOO^{2-}$
• ammonium	NH_4^+	• cyanide	CN^-	• perchlorate	ClO_4^-
• benzoate	$C_6H_5COO^-$	• dichromate	$Cr_2O_7^{2-}$	• permanganate	MnO_4^-
• hydrogen carbonate (bicarbonate)	HCO_3^-	• dihydrogen phosphate	$H_2PO_4^-$	• phosphate	PO_4^{3-}
• hydrogen sulphate (bisulphate)	HSO_4^-	• ferricyanide	$Fe(CN)_6^{3-}$	• silicate	SiO_3^{2-}
• hydrogen sulphide (bisulphide)	HS^-	• ferrocyanide	$Fe(CN)_6^{4-}$	• stearate	$C_{17}H_{35}COO^-$
• hydrogen sulphite (bisulphite)	HSO_3^-	• glutamate	$C_5H_8NO_4^-$	• sulphate	SO_4^{2-}
• borate	BO_3^{3-}	• hydrogen phosphate	HPO_4^{2-}	• sulphite	SO_3^{2-}
• bromate	BrO_3^-	• hydroxide	OH^-	• tetraborate	$B_4O_7^{2-}$
• carbonate	CO_3^{2-}	• hypochlorite	ClO^-	• thiocyanate	SCN^-
• chlorate	ClO_3^-	• iodate	IO_3^-	• thiosulphate	$S_2O_3^{2-}$
• chlorite	ClO_2^-	• nitrate	NO_3^-	• tripolyphosphate	$P_3O_{10}^{5-}$
		• nitrite	NO_2^-		

SOLUBILITY OF SOME IONIC COMPOUNDS IN WATER AT 298 K (25°C)

ION	Group IA		NH_4^+	NO_3^-	CH_3COO^-	Cl^- Br^- I^-	SO_4^{2-}	S^{2-}	OH^-	PO_4^{3-} SO_3^{2-} CO_3^{2-}
	alkali metal ions	H^+ (H_3O^+)								
SOLUBILITY >0.1 mol/L (VERY SOLUBLE)	All	All	All	All	Most	Most	Most	Group IA Group IIA NH_4^+	Group IA NH_4^+ Sr^{2+} Ba^{2+} Tl^+	Group IA NH_4^+
SOLUBILITY <0.1 mol/L (SLIGHTLY SOLUBLE)	None	None	None	None	Ag^+	Ag^+ Pb^{2+} Hg_2^{2+} Cu^+ Tl^+	Ca^{2+} Sr^{2+} Ba^{2+} Ra^{2+} Ag^+ Pb^{2+}	Most	Most	Most

TEACHER QUESTIONNAIRE FOR CHEMISTRY 20

This is a course designed in a new distance-learning format, so we are interested in your responses. Your constructive comments will be greatly appreciated so that a future revision may incorporate any necessary improvements.

Teacher's Name _____ Area of Expertise _____

School Name _____ Date _____

Design

1. The modules follow a definite systematic design. Did you find it easy to follow?

   ❑ Yes ❑ No If no, explain.

   _____

   _____

2. Did your observations reveal that the students found the design easy to follow?

   ❑ Yes ❑ No If no, explain.

   _____

   _____

3. Did you find the Learning Facilitator's Manual helpful?

   ❑ Yes ❑ No If no, explain.

   _____

   _____

4. Part of the design involves stating the objectives in student terms. Do you feel this helped the students understand what they were going to learn?

   ❑ Yes ❑ No If no, explain.

   _____

   _____

5. The Learning Facilitator's Manual contains Assignment answers and a sample test. Did you find these helpful?

❑ Yes ❑ No If no, explain.

_____

_____

6. Did the Follow-up Activities prove to be helpful?

❑ Yes ❑ No If no, explain.

_____

_____

7. Were students motivated to try these Follow-up Activities?

❑ Yes ❑ No If no, give details.

_____

_____

8. Suggestions for computer and video activities are included in the course. Were your students able to use these activities?

❑ Yes ❑ No Comment on the lines below.

_____

_____

9. Were the assignments appropriate?

❑ Yes ❑ No If no, give details.

_____

_____

10. Did you fax assignments? ❑ Yes ❑ No

11. If you did fax, did you get satisfactory results from using this procedure?

❑ Yes ❑ No If no, give details.

_____

_____

Instruction

1. Did you find the instruction clear?

   ❑ Yes ❑ No If no, give details.

   _____

   _____

2. Did your observations reveal that the students found the instruction interesting?

   ❑ Yes ❑ No If no, give details.

   _____

   _____

3. Did you find the instruction adequate?

   ❑ Yes ❑ No If no, give details.

   _____

   _____

4. Was the reading level appropriate?

   ❑ Yes ❑ No If no, give details.

   _____

   _____

5. Was the work load adequate?

   ❑ Yes ❑ No If no, give details.

   _____

   _____

6. Was the content accurate and current?

   ❑ Yes ❑ No If no, give details.

   _____

   _____

7. Did the content flow consistently and logically?

❑ Yes ❑ No If no, give details.

_____

_____

8. Was the transition between booklets smooth?

❑ Yes ❑ No If no, give details.

_____

_____

9. Was the transition between print and media smooth?

❑ Yes ❑ No If no, give details.

_____

_____

Additional Comments

_____

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Thanks for taking the time to complete this survey. Your feedback is important to us.

Fax Number: 674-6686

Instructional Design and Development Unit
Alberta Distance Learning Centre
Box 4000
Barrhead, Alberta
T0G 2P0

Note: Please ensure that each of your students has completed and forwarded a copy of the Course Survey.

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Chemistry 20

Learning Facilitator's Manual

L.R.D.C.
Producer

1993